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MINI-FERTILIZER PLANT PROJECTS

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This document presents major results of work under the element Studies on Fertilizer Industries in UNIDO's programme of Industrial Studies 1982/83.

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Preface

This study has been prepared in response to the recommendation of the Third Consultation Meeting on the Fertilizer Industry held in Sao Paulo, Brazil, 29 September - 2 October 1980. It will be presented to the Fourth Consultation, to be held in New Delhi in January, 1984.

Its preparation has been possible through a special contribution to UNIDO from the People's Republic of Hungary in the form of assistance extended by the Hungarian Chemical Industries Engineering Centre (VEGYTERV). VEGYTERV has implemented this study in co-operation with the Division for Industrial Studies, Sectoral Studies Branch.

Extensive use was made of the documentation and material presented at the mini-fertilizer seminar organized in November, 1982 in Lahore, Pakistan by the UNIDO secretariat and the Pakistan National Fertilizer Company. Special questionnaires, direct contacts and personal visits were made to contractors, plant owners and equipment manufacturers of fertilizer plants in both the industrialized and the developing countries in order to collect material for the study. The Food and Agriculture Organization (FAO) and the World Bank also supplied valuable information and material for this study. The main contribution comes, however, from the Hungarian Chemical Industries Engineering Centre (VEGYTERV) who has prepared the study for printing, based on its own knowledge and experience, contributions from UNIDO as well as the above-mentioned material.

UNIDO expresses its gratitude for the work done by VEGYTERV.

The details of the work executed and the contributions received from different information sources are reviewed in Appendix 1/1 which together with other statistical material is being issued separately as an addendum to this document.

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1. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

1.1 Summary of the methodology adopted

Based on conceptual deliberations - given in detail in the Appendix 3/1 - the total investment costs for a fertilizer plant located in a developed country was established, as well as for an identical plant in a developing country, at two selected locations, one in sea-side location and one in a remote location. The total investment cost as well as the operating cost of small-size plants for various fertilizers were calculated for plants located in these selected sites. Different feedstocks were considered in the case of nitrogen fertilizers, namely, natural gas, coal and fuel oil.

The economics, with regard to investment, operating, and farm gate costs were compared for the various fertilizer plants located at the selected locations in order to compare the competitiveness of each plant within the same location as well as the competitiveness between the various locations.

It should be noted that, in calculating the operating costs rather conservative on-stream factors were considered for the developing country locations (i.e. 75 per cent for large plants and 90 per cent for small plants). If these factors are elevated the competitive position of plants in the developing region will register an obvious improvement.

1.2 Summary of the findings and conclusions

The information material collected, their processing the technical and economic evaluation executed led to findings and conclusions discussed in detail in the relevant chapters. These conclusions can be summarized in the following:

General

1. In spite of the actual world economic situation and the depressed fertilizer market situation the forecast made by the different international organizations (FAO, World Bank, IFDC, Fertilizer Institute, UNIDO, etc.) and the individual experts - although they may differ in actual

figures, show the same trend. The food problem, the agricultural development needs, the continuous technological innovations, together with the availability of the necessary raw materials will lead to substantial consumption and production increases. From the evaluation of the different forecasts, this study came to the conclusion, that the following demand/supply balance of nitrogen fertilizers can be expected in million tons nitrogen:

Demand/Supply balance of nitrogen fertilizers

(million tons N/year)

	81/82	82/83	83/84	84/85	85/86	86/87	87/88
Available supply	62,52	62,37	67,52	70,74	73,17	74,77	75,69
N fertilizer demand	60.44	61,38	63,74	66,99	69,35	71,78	74,20
Surplus	2,12	0,99	3,78	3,75	3,82	2,99	1,49

Source: The UNIDO/FAO/World Bank Working Group on
Fertilizers
July , 1983

2. More new ammonia plants is expected to be built in the countries and locations where natural gas, at low cost, is available (Mexico, Trinidad, Algeria, Nigeria, Libya, the Near East countries, Bangladesh, Thailand, Malaysia, Indonesia, USSR). The Near East countries will become an important supplier of ammonia and nitrogen products.

3. The world demand which was 30,91 million tons P_2O_5 in 1981/82 is expected to increase to 38,2 million tons in 1987/88.

Phosphoric acid capacities will reach 37,7 million tons P_2O_5 in 1987/88 compared to 29,66 million tons in 1981/82.

4. The share of the developing countries in phosphoric acid capacity which is about 19 per cent in 1981/82 is estimated to be in 1987/88 about 29 per cent.

5. The export availability of phosphate fertilizers is expected to grow as these new capacities are located near phosphate rock supplies. World trade in phosphoric fertilizers will increase from 4 million tons in 1979 to 10 million tons in 1990. North America will continue to be the leading exporter but Africa will increase its share of the total.

6. The world potash fertilizer demand will increase from 23,9 million tons K_2O in 1981/82 to 29,67 million tons K_2O in 1987/88 and the annual growth rate is expected to be about 3,6 per cent up to 1987/88.

7. It is evident that there will be a need to establish new fertilizer capacity in order to meet the expected increase in demand. It should be noted, however, that the size of demand in many countries will be too small to justify the erection of currently known large plants. Therefore, a considerable market pressure will be exerted to the development of up to date versions of more convenient capacity sizes to meet such limited demand. The general conclusions selected to each type of fertilizer are summarized as follows:

Ammonia plants

8. The oil price adjustments, the economic slump, the general shortage of foreign exchange, high transport costs together with the problems encountered with the "jumbo" plants created a completely new world market situation both in fertilizer

products and fertilizer plants.

In this new situation, new tendencies have emerged in the nitrogen fertilizer industry and first of all in the manufacturing of ammonia leading to

- development of new, energy saving solutions by simpler, less sophisticated processes and equipment, more suitable for developing countries
- return to the old methods of synthesis gas production using other feedstocks, like coal or electrolytic hydrogen
- attention focused on the mini-plant concept.

9. As a result, several new process schemes have been worked out. All of them are well suited for implementation in the developing countries and particularly for mini-fertilizer plants.

10. On a worldwide scale the nearly monopolistic position of the natural gas as the most economic raw material for ammonia production seems to be assured at least for this decade but probably even for the next one. But in given local conditions, especially in developing countries, and for mini-plants, alternative feedstocks can present a real alternative or even the only feasible route for ammonia production.

All coal processing methods are in reality yet in the development stage, even if several of them can be referred to as realized and operative commercial plants. All processes are heavily dependent on the quality of coal. Therefore, a general assessment of the individual merits and disadvantages of the different processes would be futile.

Water electrolysis as a basis for ammonia production can be competitive only where abundant electric power is available at 3-14 Dollar/MWh.

11. The general situation of world economy, the currency problems, transport costs, experience in developing countries with either jumbo or mini-plants, the recent developments etc., justify serious consideration of the mini-plants as a viable alternative for the developing countries entering in the fertilizer production field.

It is possible now to devise new flowsheets for mini-plants having specific parameters competitive with big plants. These flowsheets will be worked out in detail and proven commercially only if the interested contractors will be persuaded that an adequate market justifies the expenses involved. Nevertheless even now with the information gathered it was possible to present two alternatives. The first is for a 150 tpd ammonia plant, the other for a 250 tpd plant. This flowsheet promises better performance than the majority of 1000 tpd plants operating at the moment with total energy requirement of around 8,3 Gcal/t NH_3 , in spite of simplified design.

Although, neither the Beijing Conference (1), nor the Lahore Meeting (2) recommend the consideration and evaluation of ammonia plant around 50 tpd capacity, this study devoted due attention to this alternative. The preliminary findings of the Lahore meeting have been confirmed: it would be possible to design such ammonia plants with not much worse characteristics as the 150 tpd one presented here, but the processing of ammonia to ready-made fertilizer would be too expensive. So for this size, the solution adopted by the People s Republic of China, producing ammonium bicarbonate directly in the ammonia plant remained as the technically and economically appropriate alternative. As the applicability of this kind of fertilizer product outside of China has to be confirmed by actual experiment - according to the recommendations of the Lahore Conference this size and process flowsheet had to be left out of consideration in this study.

12. With regard to specific investment the advantage in favour of the big plants is still observable at the developed sites, although not really significant. In all other cases the differences can be safely considered to fall within the accuracy limits. For developing countries mini-plants will not involve bigger capital costs as the same capacity realised in big units.

At remote locations, the most probable sites for mini-plants, these can be realised with less specific investment as for big units at the same site, but will still cost nearly

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1.) **Technical Conference on Ammonia Fertilizer Technology for Promotion of Economic Co-operation among Developing Countries**
Beijing, People s Republic of China, 13-28 March, 1982

2.) **Seminar on Mini-Fertilizer Plants, Lahore, Pakistan, 15-20 November 1982** two times the specific investment of a big plant in a developed site.

13. Feedstock has a strong influence on the investment cost, with roughly the same effect on all sites and capacities.

14. The production costs of the mini-plants at remote site are competitive with the big plants at the same site and the advantage in favour of the big plant in developed countries is less than the transport costs, so the mini ammonia plants are competitive even at the factory gate.

Feedstock price has a strong effect on the production costs. But capital costs are decisive: coal based processes can be competitive only with one tenth of feedstock price (on heating value basis).

Nitrogen fertilizer products

15. The costs of all the products from mini-plants (farm-gate basis) are competitive with the imported nutrient, when based on natural gas.

16. Ammonia from other feedstocks gives fertilizer products with higher farm-gate costs as the imported ones (which are based evidently on natural gas) but are still less expensive from local mini-plants as from big central plants.

17. Ammonium nitrate production needs higher investment and therefore, has higher production and farm-gate prices than urea in every case investigated, but the differences tend to become smaller with decreasing capacity.

18. The above results demonstrate unequivocally that mini-fertilizer plants are competitive both with imported products and with big plants erected in the country when farm-gate prices are compared.

Phosphate Fertilizers

19. For the purpose of mini-plant study, only sulphuric acid route can be considered.

20. Only two selected capacities for H_2SO_4 and one size for all other products were examined. Since scale-up has no effect on the process, specific consumption figures remain essentially the same for all capacities in the mini-plant range and battery limit investment figures can be extra-

polated by the usual formula with a 0,8 as exponent. Therefore the figures computed for the sizes selected will only be improved, when bigger mini-plants will be considered.

21. The farm-gate price of the mini-plant product will be in every case by far the most advantageous.

22. The very big differences between SSP and TSP production underline the conclusion that for mini-plants the right product is SSP.

23. The more sophisticated MAP and DAP involves even higher investment costs and seem not very appropriate for mini-plants in developing countries.

24. NPK plants can form a viable alternative only if ammonia, nitric acid and phosphate processing facilities are on the same site - a case seldom encountered.

Potential markets for mini-plants

25. In order to evaluate the market possibilities for mini-plants, this study considered the fertilizer demand both in quantity and type of product, the availability of raw materials, and other necessary factors (energy, infrastructure, skill, etc.) for the implementation of manufacturing units with the aim to assess how many countries are potential builders of mini-plant, how many of them can be considered for the erection of both mini- and big plants for the different fertilizers.

Product consumption

26. More than one third of the 91 countries examined consumed less than 10000 tpy N and 60 per cent of them could not reach the level of 40000 tpy N that refers to as a mini-scale unit capacity (150 tpd) for ammonia. On the other side a large number of them consumed more than 100000 tpy N even 14 countries consumed over 200000 tpy N including China, India, Mexico of which consumption rose above million tpy N.

27. As for the phosphate fertilizer, half of the countries were below a consumption level of 10000 t P_2O_5 and at the same time 13 of them consumed more than 100000 tpy P_2O_5. It is clear that there is a strong degree of polarization in the consumption of nitrogen and phosphate fertilizers. This manifestation is, however, not evident in

the consumption of potassic fertilizer.

28. Comparing the recent share in Table 4.1-2 with the forecasts in Tables 4.2-4 and 4.2-5 in case of nitrogen, it can be seen that even in the year 2000 the number of countries, 25 or 27,5 per cent, will not reach the level of 10000 tpy N. On the other hand, the number of countries consuming more than 200000 tpy will rise from 14 in 1981/82 to 26 in 2000, presenting a further polarization in consumption pattern of the developing countries.

29. The main ranges in nitrogen consumption in 2000 will be the consumption above 200000 tpy N with 28,6 per cent and the consumption level 1000 - 10000 tpy N with 24,2 per cent.

30. Similar changes can be forecast for the P_2O_5 consumption. There will be a difference in case of K_2O consumption because the main ranges will be the consumption levels from 1000 to 10000 and from 10000 to 40000 amounting about 32 per cent and 27,5 per cent, respectively. This is corresponding to the forecast philosophy that in this period the developing countries will not reach the N:P:K ratio than that observed with the developed economies.

Raw material

31. The raw material potential of developing countries was studied by regions. Almost half of the countries studied have natural gas reserves and 48 of them can or will be able to produce crude oil. 40 developing countries have coal/lignite deposits. Since in the developing countries very large areas have not been surveyed at all it is reasonable to suppose, that most developing countries will discover adequate coal deposits.

32. The reserves of phosphate rock are wide-spread. Some 34 countries of the world are producers, and 23 of the developing countries belong to 91 countries studied. Among them Morocco is the most important having about 70 % of total identified resources. Including Morocco, 41 developing countries surveyed have phosphate rock deposits.

33. In 1981/82 there were 12 potash producing countries two of them, China and Chile, were developing countries and their production reached 51.000 tons K_2O amounting almost to 0,2 per cent of world production. Another 14 countries have potash deposits, including Congo which

plans to develop its closed mine. Other developing countries will begin the potash production. The most important would be Jordania with a total capacity of 1,2 million tpy by 1985.

Mini-plants

34. 85 mini NH_3 plants are forecast for 1990 with a total capacity of 18850 tpd NH_3. The majority of them, almost three quarters are based on natural gas at the same time only 3 of these are expected to be based on hydropower potential.

35. In the last decade of this century 130 mini NH_3 plants are forecasted amounting to a total capacity of 29400 tpd. The majority of which (about 67 per cent) will be based on natural gas but coal as raw material will assume increasing importance with its share increasing to 19 per cent in 1990 and 28 per cent in the last decade of the century.

Majority of the plants considered both in Points 34 and 35 will be erected in countries where no big plants exist or will be built in the same period, but about 25 % can be forecast in countries where big plants also exist or will be erected.

36. For phosphate fertilizers 42 units are to be established up to 1990. In the last decade of the century 68 units are forecasted, amounting total new capacities of 3780 tpd P_2O_5 and 6120 tpd P_2O_5, respectively.

General Conclusions

37. Mini-fertilizer plants present an advantageous option for most developing countries for solving their fertilizer supply problems (wholly or partially). The actual technical level and the development work under way gives tha possibility to erect mini-plants situated near to the markets, which can be implemented with competitive capital and operation costs when compared both to the imported products and those coming from big units realised in the country - when the whole supply line to the farm gate is considered.

38. Process technology for all fertilizer production steps is available for mini-plants and no further action is needed with the exception of the ammonia process. Engineering firms are actively pursuing development work in this field but need further encouragement.

39. The realisation of mini-plant opens incomparably wider possibilities for the local participation in the equipment manufacture, erection and building works, but presents an excellent opportunity for the development of local works and skills for the maintenance, spare part production and other services an important contribution to the general industrialization of the country as well as, co-operation among developing countries in all above activities.

40. In order to establish a true agricultural government policy and work out the measures to be undertaken the most important task for a developing country is to work out or let work out a study on the national fertilizer supply system, taking into account:

- agricultural production with its development perspectives, needs and economic possibilities
- raw material situation
- the geographic situation and the transport system
- the infrastructural situation
- capital and financing resources
- man power (skilled) situation
- other relevant factors

and work out all reasonable supply alternatives from the total import of all fertilizer products to a total self reliance or even export, including the different product mix alternatives for an adequately chosen period (10-25 years) and by optimisation select the most suitable combination and define the tasks of the authorities for supporting the goals identified. This will identify the right place for the mini-plants in this supply scheme.

1.3 Recommendations

Based on the findings and conclusions, this study puts forward the following recommendations:

1.) It is strongly recommended that UNIDO place special emphasis on continuing its activities in promoting the development and use of mini-fertilizer plants in the developing countries through the convening of seminars on regional levels and a wider dissimination of studies on this subject to the developing countries in order to increase the awareness of the developing countries on the advantages of the mini-fertilizer plant alternative.

2.) UNIDO, together with other international organizations, should encourage by all means available to them the development and commercialization of processes related to the mini-fertilizer plants.
This should be done, among others, through:
- the elaboration of organization arrangements whereby developed and developing countries could initiate steps to support research activities related to the development of mini-fertilizer plants compatible with the needs of developing countries, to be undertaken by various institutions and firms;
- establishing a joint programme for the development of process designs, pilot plants and commercial scale of mini-fertilizer plants;
- organizing a seminar to which major engineering companies, research and development institutions and financial and planning organs from the developed and developing countries would be invited to participate and promote the idea and application possibilities of mini-fertilizer plants.

3.) To undertake special activities promoting co-operation among developing countries for the development of mini-fertilizer plants, with particular emphasis on joint R and D for the development and adaptation of mini-fertilizer plant technologies.

4.) To undertake an in-depth study on "fertilizer supply planning system" in which all technical, economic, legal and other developmental aspects are considered. The study should aim at helping decision-makers in the developing countries at national and regional levels to take decisions on the choice of type of fertilizer, capacity, process technology and procedure in building a fertilizer plant.

2. AN OVERVIEW OF THE FERTILIZER INDUSTRY IN THE 1980's

2.1 Development during the period 1975-1981

2.1.1 Demand/supply situation

The food deficit in the world is increasing at an alarming rate. At the same time, as a result of growing world population, the amount of arable land per person continues to decline in general, especially in the developing countries. The growth in fertilizer use is therefore one of the essential factors, warranting the growth of world food production.

Prior to 1974 fertilizer demand developed at a relatively stable rate. In 1975 world consumption declined for the first time in recent history. In 1979/80 and 1980/81 declines occured again in some major areas, including North America, Western and Eastern Europe. As can be seen from Table 2-1, the fertilizer market became characterized by periods of oversupply, followed by brief periods of shortages.

Table 2-1

World demand/supply balance

(million tons of nutrients)

	75/76	76/77	77/78	78/79	79/80	80/81	81/82
Demand	90.4	96.2	100.5	108.0	111.7	116.0	115.3
Available supply	88.6	94.4	101.9	108.4	112.5	117.7	120.6
Balance	- 1.8	- 1.8	0.4	0.4	0.8	1.7	5.3

Source: Based on FAO paper FERT/83/2, September 1982 and on the paper of the UNIDO/FAO/World Bank Working Group on Fertilizers, July 1983

Demand for fertilizer continues to increase annually at a rate of 4-8 million tons of which 3-4 million tons is in nitrogenous and the balance in phosphate and potash fertilizers. The largest portion of this increased demand can be attributed to the developing countries such as the subcontinent of Asia and Central and South America. In Africa, where the food deficit is equally great, the demand for fertilizer remains at the lowest level.

This inequality between the various regions in fertilizer use indicates the existence of large potential demand and the possibility for further development of the fertilizer industry.

The development of world production of fertilizers is presented in Table 2-2. The production of nitrogen, Phosphorous and Potash compounds was in 1980/81 in order of 125 million tons in pure nutrients and has increased by 32 per cent towards 1975/76 (Table 2-2 and 2-3). However, the effective fertilizer supply was about 6 per cent less each year, since several million tons have been used for technical purposes, further processing and were lost by transport, storage and handling.

Table 2-2 World production of fertilizer nutrients

	N			P_2O_5			K_2O		
	mill. tons	growth rate	1975/76 =100	mill. tons	growth rate	1975/76 =100	mill. tons	growth rate	1975/76 =100
1975/76	43,9	-	100	26,1	-	100	23,4	-	100
1976/77	47,6	8,4	108,4	27,7	6,1	106,1	25,0	6,8	106,8
1977/78	51,4	8,0	117,1	30,4	9,7	116,5	25,5	2,0	109,0
1978/79	55,9	8,8	127,3	32,2	5,9	123,4	26,2	2,7	112,0
1979/80	59,8	7,0	136,2	33,5	4,0	128,4	25,9	-1,2	110,7
1980/81	62,7	4,8	142,8	34,4	2,7	131,8	27,4	5,8	117,1

Source: FAO Fertilizer Yearbook 1979,1980, 1981.

The production of the three nutrients grew much faster in the developing than in the developed countries. During the last five years the total production increased in developing countries by 90.8 per cent, and in the developed countries only by 21.6 per cent (Table 2-3).

Table 2-3

Production of fertilizer nutrients in developed and developing countries

(million tons)

	1975/76	1976/77	1977/78	1978/79	1979/80	1980/81
All developed countries, million tons	80.2	84.6	88.1	92.7	94.9	97.5
growth, %	100	105.5	109.8	115.6	118.3	121.6
All developing countries, million tons	14.2	16.2	19.1	21.6	24.1	27.1
growth, %	100	114.1	134.5	152.1	169.7	190.8
Total world million tons	94.3	100.8	107.3	114.3	119.0	124.6
growth, %	100	106.9	113.8	126.2	126.2	132.1

Source: FAO Fertilizer Yearbook, 1981

2.1.2 Development of capacity and capacity utilization

To supply the growing demand between 1975-1981, additional capacities were built all over the world, however, much more extensively in the developing countries, where several new fertilizer production centres have emerged. Parallelly, a number of old and less efficient plants in the developed world have been closed or idled. Except for potash this transformation has changed the pattern of capacity share between the developed and developing countries (Table 2-4 and 2-5) (1).

Table 2-4

Share of developed and developing countries in fertilizer capacity development

(per cent)

	Ammonia N Capacity 1975	Ammonia N mid 1981	Phosphoric Acid P_2O_5 Capacity 1975	Phosphoric Acid P_2O_5 mid 1981	Potash K_2O Capacity 1975	Potash K_2O mid 1981
Developed countries	76.9	70.8	83.2	81.3	99.7	99.9
Developing countries	23.1	29.2	16.8	18.7	0.3	0.1
Total world	100.0	100.0	100.0	100.0	100.0	100.0

Source: Based on paper of FAO/UNIDO/World Bank Working Group on Fertilizers, June 1982

1.) All the capacity data are based on paper of FAO/UNIDO//World Bank Working Group on Fertilizers, June, 1982.

Table 2-5. CAPACITY CHANGE, BY REGIONS

Region	Thousand tons of N, P_2O_5, K_2O											
	Ammonia /1975 - 1986/				Phosphoric acid /1975 - 1986/				Potash /1975 - 1986/			
	Additional /+/		Closed /-/ or idled a/		Additional /+/		Closed /-/ or idled		Additional /+/		Closed /-/ or idled	
Developed Market Economies	12,578	/22,4%/	8,613	/92,7%/	3,289	/25,4%/	903	/70,5%/	6,361	/37,8/	1,952	/86,7%/
North America	7,532		4,241		2,445		496		3,551		1,032	
Western Europe	4,523		3,198		448		317		1,830		920	
Others	523		1,174		396		90		980		0	
Developing Market Economies	19,667	/35,0%/	522	/5,6%/	6,767	/52,3%/	377	/29,5%/	1,098	/6,5%/	300	/13,3%/
Africa	590		0		3,345		130		0		300	
Latin America	5,542		0		1,361		89		378		0	
Near East	5,188		109		1,236		158		720		0	
Far East	8,347		413		825		0		0		0	
Centrally Planned Economies	23,972	/42,6%/	153	/1,7%/	2,880	/22,3%/	0		9,370	/55,7%/	0	
Asia	6,641		153		0		0		0		0	
Eastern Europe	17,331		0		2,880		0		9,370		0	
All Developed Countries	+29,909	/53,2%/	-8,613	/92,7%/	+6,169	/47,7%/	-903	/70,5%/	+15,731	/93,5%/	-1,952	/86,7%/
All Developing Countries	+26,308	/46,8%/	-675	/2,3%/	+6,767	/52,3%/	-377	/29,5%/	+1,098	/6,5%/	-300	/13,3%/
World Total	+56,207	/100%/	-9,288	/100%/	+12,936	/100%/	-1,280	/100%/	+16,829	/100%/	-2,252	/100%/

Source: Based on paper of FAO/UNIDO/World Bank Working Group on Fertilizers, June 1982.

a/ Idled plants are those which are mothballed until economic conditions are such as to bring them into production. Closed plants are those permanently closed and will not be brought into operation regardless of economic conditions.

Around 47 per cent of new ammonia and 52 per cent of new phosphate capacities were established in developing countries. At the same time most of the closed or idled capacities were located in the developed countries; i.e. 93 % of ammonia and 70 % of the phosphate.

2.1.2.1 World ammonia capacity

Almost all nitrogenous fertilizers are derived from ammonia. Its capacity in mid 1975 was 67.6 million tons N and increased to 91.4 million tons N in the mid 1981. During this period new ammonia plants have brought 31.8 million tons additional capacity, however, around 8 million tons of existing capacity were closed or idled, mainly in North America, Europe and Japan.

New important ammonia capacity has been established in Mexico, Trinidad, Brazil, Egypt, Qatar, Turkey, India, Indonesia, South Korea, Pakistan as well as in the USSR, Romania, China, North Korea, U.S.A. and Canada.

Assuming that the whole nitrogenous production derives from ammonia, its capacity utilization was 62 per cent in 1975/76 and 68.6 per cent in 1980/81.

2.1.2.2 World phosphoric acid capacity

Similar to ammonia, phosphoric acid is the essential intermediate in phosphate fertilizer production. Its capacity increased from 25.5 million tons P_2O_5 in 1978/79 to 29.66 million tons in 1981/82. Phosphoric acid plants were closed in the U.S.A., France, United Kingdom and Japan and new capacities were implemented in the U.S.A., Yugoslavia, Australia, Israel, Morocco, Tunis, Brazil, Syria, Turkey and the USSR.

Although the development of new capacities in the developing countries, mainly in Africa, was impressive, the share of the developed world in phosphoric acid capacity remains relatively high (Table 2-4).

2.1.2.3 World potash capacity

Potash is obtained from underground deposits situated mainly in North America, Western and Eastern Europe. These regions are the main producer centres in the world. The total capacity of potash (K_2O) increased from 29.5 million tons in 1975/76 to 33.4 million tons in 1981/82. Altogether two of the developing countries, China and Chile, produce potash and their share in the world production is less than 0.2 %.

Capacity were closed in the U.S.A., France and the German Federal Republic as well as in Congo, where the mine was flooded. However, new mines have been opened in the USSR, German Democratic Republic, United Kingdom, Spain, France, German Federal Republic and Canada.

2.1.3 Development of fertilizer consumption

2.1.3.1 World consumption

According to FAO statistics world consumption of three main nutrients: nitrogen (N), phosphate (P_2O_5) and potash (K_2O) grew in 1980/81 to 116 million tons or 28.4 per cent over the year 1975/76. The average annual growth rate for the last five years was 5.7 per cent, but the rates of increase to the previous year slowed down from 9.3 per cent in 1975/76 to 3.3 per cent in 1979/80 and 3.3 per cent in 1980/81.

The primary cause for this performance was the situation in the developed countries where consumption of fertilizers, especially in the last three years was practically stagnant (Table 2-6).

The developing countries' consumption increased in 1980/81 almost 86 per cent over the year 1975/76 and the average rate of growth was 17.2 per cent. Nevertheless two thirds of fertilizers were as hitherto consumed in the developed countries (Table 2-6).

Table 2-6 World Consumption of Fertilizers

	Developed Countries			Developing Countries			World Total		
	million tons	growth rate	1975/76 =100	million tons	growth rate	1975/76 =100	million tons	growth rate	1975/76 =100
1975/76	69.8	-	100.0	20.6	-	100.0	90.4	-	100.0
1976/77	73.0	4.6	104.6	23.6	14.6	114.6	96.7	7.0	106.9
1977/78	72.9	-0.1	104.5	28.3	19.9	137.4	101.2	4.7	111.3
1978/79	77.5	6.3	111.0	31.3	10.6	151.9	108.8	7.5	121.3
1979/80	78.0	0.6	111.7	34.4	9.9	167.0	112.4	3.3	124.3
1980/81	77.8	-0.2	111.5	38.3	11.3	186.0	116.1	3.8	128.4
1981/82	77.2	-0.8	110.5	38.1	-0.5	185.0	115.3	-0.7	127.5

Source: FAO Fertilizer Yearbook, 1981

Paper of the UNIDO/FAO/World Bank Working Group on fertilizers, July 1983

Among the various factors responsible for the lower growth of consumption of chemical fertilizers in the world the more significant were the following:

(a) high real cost of fertilizer to the farmer, due to the increased cost of production (raw materials, energy, labour, etc.) and distribution;

(b) less favourable crop/fertilizer relationship because of unfavourable crop prices and high interest rates on borrowed funds in developed countries as well as due to the bad weather in some years and in some regions of the world, e.g. in the United States and in the USSR in 1977/78 and 79/80;

(c) lack or insufficiency of local fertilizer production in the majority of the developing countries, where real consumption is low, though the potential for their use is great. The existence of local fertilizer production usually leads to an accelerated growth in the indigenous demand;

(d) foreign exchange restrictions limiting importation of fertilizers, as well as lack of governmental support such as rural credits, agronomic service, training, subsidies, price policy, etc.;

(e) lack of marketing and agronomic infrastructure and a technical incapacity to deliver and distribute fertilizers to farmers.

2.1.3.2 Regional development of consumption

According to FAO Statistics North America, Western and Eastern Europe had slow growth rate that nearly approached a stagnant condition.

In Africa the consumption grew in five years by 5o per cent, but the absolute figure of consumed fertilizer nutrients in 1980/81 amounted to only 1.5 million tons, which constituted 1.3 per cent of total world consumption.

Latin America had a low performance rate in 1978/79 influenced mainly by a market slow-down in Brazil and Mexico.

The Near East's growth rate was 50 per cent over the five year period. The Far East (including China and Korean Democratic Republic) experienced more than three times the world's average growth rate. The main countries that contributed to this region's performance were China, India, Pakistan and Indonesia.

2.1.3.3 Development of fertilizer consumption

The development of fertilizer consumption by main nutrients is given in the Appendix 2/1, in Table 1 and 2. It is shown that in 1980/81 world nitrogenous fertilizer consumption increased by 39.9 per cent to 60.3 million tons of N. The growth rate in developing countries was 105 per cent while in the developed world it was only 15.6 per cent.

The consumption of phosphate fertilizer in the same period of time increased by 25 per cent to 31.5 million tons. Also here the gain of developing countries appears impressive (79 per cent for five years).

Potash fertilizer consumption increased by 13 per cent (81.8 per cent in developing and 5.2 per cent in developed. countries).

The share of developing countries in nitrogen consumption increased from 28.2 per cent to 41.1 per cent, in phosphate consumption from 21.4 tp 30.0 per cent and in potash consumption from 10.3 to 16.5 per cent.

Although the developed countries dropped their share in world fertilizer consumption from 77.9 per cent in 1975/76 to 67 per cent in 1980/81, the developing countries consumption still lags for behind that of the developed world both in total and per hectare.

In developed countries total fertilizer consumption was 115.8 kgs per hectare arable land and permanent crops in 1980, however, in the German Federal Republic the total consumption of the three nutrients was 471.5 kgs, while in the German Democratic Republic it was 325.2 kgs and in France 300.8 kgs.

At the same time it was 46 kgs and 37.6 kgs and 9.7 kgs in Latin America, Far East and in Africa, respectively. Many of them, such as Nigeria, Cameroon, Tanzania, Ethiopia, Argentina, Afghanistan, etc., used only a few kilograms of nutrients per hectare.

The fertilizer application in some countries was more or less constant and a growing factor of the economy. However, in many others it remained accidental and irregular.

2.1.3.4 Development of international trade

International trade in fertilizers increased considerably between 1976/77 and 1980/81 (Table 2-7). As world consumption increased 21 per cent in this period, so did international trade by nearly 40 per cent, of which the growth rates were! nearly 80 per cent of phosphate, 53 per cent of nitrogenous and nearly 20 per cent of potash fertilizers. Potash fertilizers remain, however, the biggest nutrient item of international trade. In 1980/81 a bulk of 16.7 million tons K_2O was traded, while 13.1 million tons N and 7.5 million tons P_2O_5.

Imports have accounted in 1976/77 for about 27 per cent of world consumption and 31.4 per cent in 1980/81. This increase was mainly in the developing countries, where in 1980/81 almost 42 per cent of totally consumed nutrients arrived from abroad, compared with 37 per cent in 1976/77. This fact took place in spite of a considerable increase in local production in some developing countries though mainly in intermediates such as ammonia and phosphoric acid and not in finished fertilizers.

Table 2-7. WORLD TRADE IN FERTILIZERS, BY REGIONS

/million tons of nutrients/

Region	Imports						Exports					
	N		P_2O_5		K_2O		N		P_2O_5		K_2O	
	76/77	80/81	76/77	80/81	76/77	80/81	76/77	80/81	76/77	80/81	76/77	80/81
Developed countries												
Market economies	3.8	5.2	1.9	2.4	8.5	9.3	5.8	8.6	3.8	6.0	9.0	11.0
Centrally planned economies	0.2	0.3	0.3	0.5	2.9	2.7	2.0	2.8	0.2	0.5	4.7	5.7
Total developed	4.0	5.5	2.2	2.9	11.4	12.0	7.8	11.4	4.0	6.5	13.7	16.7
Developing countries												
Africa	0.4	0.5	0.2	0.3	0.2	0.3	a/	a/	0.3	0.4	0.0	0.0
Latin America	1.1	1.4	0.7	0.9	1.2	1.9	0.2	0.2	a/	a/	a/	a/
Near East	1.0	1.1	0.2	0.9	0.1	0.1	0.4	1.0	a/	0.1	0.0	0.0
Far East	1.2	2.7	0.4	1.3	0.6	1.5	a/	0.5	a/	0.3	0.0	0.0
Total market economies	3.7	5.7	1.5	3.4	2.2	3.8		1.7	0.4	0.8	a/	a/
Asian centrally planned economies	1.0	2.0	a/	0.4	0.2	0.6		a/	0.0	a/	0.0	0.0
Total developing	4.7	7.8	1.5	3.8	2.3	4.4	0.7	1.7	4.0	1.0	a/	a/
Total world	8.7	13.3	3.7	6.7	13.7	16.4	8.5	13.1	4.4	7.5	13.7	16.7

Source: FAO Fertilizer Yearbook, 1980.
FAO Monthly Bulletin of Statistics, March 1982.

a/ Less than 50,000 tons.

Traditional exporters of fertilizers have been the developed markets economies. However, the share in world export of the USSR and some other centrally planned economics have grown. For the first time some developing countries, particularly in the Near and Far East regions, have demonstrated visible export activity. The most notable are the Republic of Korea, Indonesia, Kuwait and Saudi Arabia.

That new trend is still more apparent when considering the international trade of some essential fertilizer materials as ammonia and phosphoric acid. New important international exporters have emerged in the last years: USSR, Lybia, Mexico, Trinidad and Tobago, Kuwait and Qatar of ammonia trade and Morocco and Tunisia of phosphoric acid. These countries have the potential to become important exporters of finished fertilizer in the future, too.

2.1.3.5 Price movement

The peak off in nitrogen and phosphate prices in 1973/74 in connection with the quadrupling of petroleum and phosphate rock prices, as well as potash fertilizers in 1975 has lead to a reduction in the purchase of buying fertilizers by farmers. This, in turn, resulted in a rapid decline in prices of all fertilizers on international markets during 1975 and 1976.

Since 1976 prices have fluctuated and about levelled off until mid 1978. However, starting the second half of 1978 international export spot prices in current dollars have increased steadily, peaking off again in 1979 and evening out at the new, but higher level. In 1981 and 1982 a slight price decline of almost all types of fertilizers again took place.

Table 2-8 shows the development of fertilizer export spot prices in current dollars during the years 1975-1981.

The price of bagged urea for example, being in 1974 around US Dollar 385 per ton f.o.b., had fallen in 1975 to US Dollar 160 and in 1976 to US Dollar 115. In December 1977 and 1978 the average export price was US Dollar 126 and US Dollar 145, respectively. During 1979, however, the price of bagged urea increased sharply to US Dollar 200 and in 1980 to US Dollar 235. At the end of 1982 the price has again bottomed as far as US Dollar 145.

A similar trend was followed by ammonium sulphate, its price, however was US DOllar 55 at the end of 1982.

The increase in triple superphosphate price had a slightly different development. The bottom was in 1976 (US Dollar 110), then the increase was to US Dollar 127 and 140 at the end of 1977 and 1978, respectively, and a new peak off in 1978 at US Dollar 250. After the decline to US Dollar 195 in 1980, the price of TPS felt down to US Dollar 140 at the end of 1982.

Table 2- 8 . AVERAGE EXPORT PRICES OF SELECTED FERTILIZER MATERIALS

/US $/ton/

		Price in December							
		1975	1976	1977	1978	1979	1980	1981	Mid Aug. 1982
Ammonia	Fob W. Europe	150.0	110.0	90.0	90.0	155.0	160.0	180.0	130
Urea	Fob W. Europe	160.0	115.0	136.0	145.0	200.0	235.0	175.0	145
Ammonium Sulphate	Fob W.Europe	80.0	45.0	57.0	65.0	78.0	100.0	45.0	55
Phosphoric Acid	Fob US Gulf	400.0	180.0	190.0	210.0	340.0	365.0	320.0	280
Triple Superphosphate	Fob US Gulf	190.0	110.0	127.0	140.0	250.0	195.0	150.0	140
Potassium Chloride	Fob N.America	85.0	55.0	53.0	63.0	98.0	115.0	90.0	70

Source: Based on "Fertilizer International": International Price Trends.

Potassium chloride export spot prices have been steady for 1976-78, have increased in 1979 and 1980 and fallen again at the end of 1982.

Although as indicated before, there is an adequate supply capability to meet the demand for the three nutrients, these price movements reflect general inflationary increases in cost as well as periodical stronger demand (e.g. in 1973/ /79). Such cost of reasonable market force based increases are apparently tolerated by importers. It is, however, to be hoped that an artificial shortage and the accompanying high prices of 1973-75 caused by panic buying does not occur again. If it does, then prices could escalate quickly to a very high level giving a disfavourable cost/benefit ratio for the farmers and again having an adverse effect on crop production in developing countries and sustaining the boom-bust cyclical nature of the world fertilizer industry.

2.1.4 Structural changes in the fertilizer industry

2.1.4.1 Impact of cost on closure of fertilizer plants in developed countries

Increasing raw material and energy costs, inflation and a poor market are the most important factors causing the structure changes within the fertilizer industry in the world, particularly in the developed countries.

In the U.S.A., for example, a total of 4.7 million tons of annual ammonia capacity has been shut down from 1977 to 1981. There are many plants that are operating at reduced production rates. The United States, once a major nitrogen producer in the world and a net exporter are losing their position by the rising price of domestic natural gas.

In Japan the nitrogen industry closed a total of 1.2 million tons annual ammonia capacity. Over 40 per cent of the Japanese urea capacity will be closed as part of a restructuring plan.

Phosphoric acid producers in Japan are also closing about 20 per cent of the capacity in the older and smaller plants. They find an advantage in importing phosphoric acid and ammonia from the countries having raw materials. Also in Europe the markets and sources of supply are changing.

2.1.4.2 Shift of new capacities towards sources of raw materials

During the 1970's a new trend in the development of the world fertilizer industry has been initiated, which is expected to continue for the foreseeable future. With the increase of energy and raw material costs the locations of the new plants are moving towards the places adjacent to the cheap and abundant feedstock.

In latest times the following new projects have been announced in the countries having natural resources:

For ammonia/nitrogen production:

in Africa	Algeria, Egypt, Libya, Madagascar, Morocco, Nigeria, Somalia, Sudan, Tanzania, Tunesia
in Latin America .	Columbia, Equador, Mexico, Trinidad, Brazil
in Near East	Abu Dhabi, Bahrain, Kuwait, Saudi Arabia
in Far East	Bangladesh, Burma, India, Indonesia, Malaysia, Pakistan, Philippines, Thailand

For phosphoric acid and phosphate fertilizers, new capacities would be:

in Africa	Egypt, Morocco, Tunesia, Senegal, Togo
in Latin America	Belize, Mexico, Peru, Venezuela
in Asia	Philippines, Indonesia, Iraq, Syria

New or substantially extended potash capacities will be established in:

Israel, Jordan, Mexico, Brazil,
China.

2.2 Major technological developments and tendencies

The production of three nutrients in fertilizers was in 1980/81 in the order of 125 million tons and is expected to increase to 173 million tons in 1990/91. A considerable part of the new capacity will be installed in the developing countries, particularly where local raw materials are available.

On analysing the evolution of the fertilizer industry, it is noted that there have been no major breakthroughs in the chemical technology during the past decades.

Basically, the fertilizer industry continues to be a derivate of ammonia, sulphuric acid, phosphate rock and potash salts. The change, which has taken place in the meantime has mainly been of a physical nature. For example, the unit capacity of all manufacturing plants has grown considerably. Thus, whereas an ammonia plant of 200 t/d or a sulphur acid unit of 100 t/d was not considered small three or four decades ago, a 1000 t/d unit would not be considered exceptionally large in the seventies.

There have been also considerable changes in downstream conversion of basic chemical raw materials into more concentrated final products. The conversion into high analysis fertilizers like urea, triple superphosphate, ammonium phosphates have reduced the share of low analysis products such as ammonium sulphate, single superphosphate, ammonium nitrate etc., in the total production and consumption of fertilizers. For example the fertilizer production in the developing countries is almost entirely based on urea, because it can be delivered to farmers at less cost per unit N than in any other form. Other development is the granulation of fertilizers, which has substituted pulverous products from the past.

The development of the fertilizer industry can be attributed to the accelerated expansion of the fertilizer market in developed countries. In general, when the market expanded it has been found more economical to build large tonnage plants instead of multiplying the number of small units. This way, the industry benefited from the economy of scale and a general incrase in efficiency.

On the other hand, this situation does not necessary apply to the developing countries, where the fertilizer market size is comparatively limited. This fact and high investment which is necessary for large units and for the infrastructure have in many cases hampered the development of the fertilizer industry in these countries.

The present fertilizer industry has been developed under conditions of low-cost energy, which encourage equipment-intensive and energy-intensive manufacture and long distance transport. The rise of energy prices directly caused a rise in fertilizer prices. Consequently it gives a strong incentive to develop processes that have higher energy efficiency.

The general trend in technological development in fertilizer industry could be summarized as those directed towards:

a.) energy saving technologies
b.) improvement in the input/ /output coefficients, i.e. higher yield from some raw materials,
c.) improved application of fertilizer i.e. decrease the amount of work
d.) diversification of raw materials i.e. new sources of raw materials and improved method of the utilization of minerals of low concentration
e.) long-term research in direct plant fixing and new biological varieties (genetic engineering).

2.2.1 Ammonia

In ammonia plants the cost of energy is by far the biggest contribution to the cost of the product, accounting for about 70 per cent of the total cost. The technology, when based on natural gas (75 per cent of world production) requires about 8.5 - 9.0 Gcal/ton liquid ammonia produced.

Overall energy efficiency of current production systems is still below 50 per cent.

In many of the plants that are currently being designed, changes are being made to improve overall efficiency. Of these more important are:

- combustion air preheat and process air preheat are being installed. The feed is also being preheated to higher temperatures;
- catalysts of shift conversion are improving to keep down CO and reducing inerts;
- heat requirement for CO regeneration is eliminated;
- inerts (H_2O, CO, N) are removed by criogenic purification, lowering the energy reguirements for recirculation and in the purge gas loss;
- newer reactors and some changes in catalytic temperature in synthesis convertor.

All these improvements are expected to reduce energy requirements to around 7.2 - 7.3 Gcal/ton ammonia.

2.2.2 Sulphuric acid

Sulphuric acid is the major cost element in producing wet phosphoric acid. Thus, the new sulphuric acid plants are getting more energy efficient and some producers are beginning to be net exporters of energy (steam or electricity).

The changes in the sulphuric acid technology are aimed at minimizing internal energy consumption and maximizing energy recovery. The savings are tied to the highly exothermic production process. The heating value of a ton of sulphur is equivalent to that of 2 bbl of oil, and each ton of sulphur can generate three tons of steam, the production of which otherwise would cost Dollar 40. "The sulphuric acid plant is really a power plant, that just happens to make sulphuric acid, too" (1). Rising prices of electricity justify the installation of a turbogenerator to put the steam to work generating electricity.

1.) Chemical Week, February 10, 1982

The new plants can make the steam pay off because they produce the steam at 900 psi (about 60 bar) instead of 300 psi (about 20 bar) in the old units. They also make more steam. A typical 1970's plant could generate 1.14 tons of steam per ton of acid while the 1980's plant gets more about 1.3 tons of steam for the same amount of acid produced.

Another energy saver is lowering the pressure drop in the catalytic converter, using new catalysts. The lowering of pressure saves electric power or high-pressure steam.

2.2.3 Phosphoric acid

In the past few years phosphoric acid has been the source of more than 90 per cent of the new phosphate fertilizer production and this trend is expected to continue in the foresceable future.

The overall energy requirement to produce phosphoric acid is not very high, since energy component is associated with phosphate rock and sulphur mining and storage. Nevertheless the methods of minimizing the energy input are of importance for the fertilizer industry.

For saving energy the following manufacture steps are improving:

- wet-grinding of phosphate rock has found wide acceptance. By wet-grinding the mill size is reduced and grinding efficiency is higher. The electric power consumption is reduced by 30 per cent;
- the hemihydrate process of phosphoric acid is extended, since it does not need heat energy in comparison with the conventional dihydrate process which requires steam at about 1.9 Gcal per ton of P_2O_5 (as 54 per cent acid).

2.3 Prospect of fertilizer development in the 1980's

2.3.1 Development of demand and supply (capacities)

Forecasts of expected demand and supply capability for the three nutrients up to 1987/88 were prepared by the FAO/UNIDO/World Bank Working Group on Fertilizers in papers dated June/July 1983. Similar exercises were undertaken by the International Fertilizer Development Centre and TVA National Fertilizer Development Centre taking into account trends and events which took place during in last two years. Based on the figures and assumptions of these exercises the following expected development of demand/supply has been designed.

2.3.1.1 Nitrogen fertilizer

The demand for nitrogenous fertilizers is expected to grow on average at 3.5 per cent annually, during the years from 1981/82 up to 1987/88. Consequently the total world demand in 1987/88 will be around 74.2 million tons N, 22.8 per cent more than 1981/82 (Table 2-9).

The share of developing countries will remain in this period almost constant, around 43-44 per cent.

The increase of supply capabilities of nitrogenous fertilizers can be illustrated by the expected anhydrous ammonia capacity development, which is the basic for nearly 100 per cent of nitrogenous fertilizers. It is expected to reach 120 million tons nitrogen in 1987/88.

Estimates of capacity are based on existing capacities plus information on new projects under construction or firmly committed. Closures have been taken out of capacity only when known to be permanently closed; idle plants have been retained since they could resume production when conditions are judged suitable for them to do so, by their owners.

Table 2-9 Demand forecast for N fertilizer

/million tons of N/

	1981/82 (actual)	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88
Developed market economies	22,26	20,88	21,54	22,79	23,45	23,98	24,50
North America	11,02	9,58	10,24	11,29	11,65	11,88	12,10
West Europe	9,76	9,80	9,80	9,90	10,20	10,50	10,80
Oceania	0,27	0,30	0,30	0,30	0,30	0,30	0,30
Others	1,21	1,20	1,20	1,30	1,30	1,30	1,30
Developing market economies	12,76	13,60	14,50	15,50	16,40	17,40	18,40
Africa	0,66	0,70	0,80	0,90	0,90	1,00	1,00
Latin America	2,86	3,10	3,20	3,40	3,60	3,80	4,00
Near East	2,11	2,30	2,50	2,70	2,80	3,00	3,10
Far East	7,13	7,50	8,00	8,50	9,10	9,60	10,30
Centrally planned economies	25,42	26,90	27,70	28,70	29,50	30,40	31,30
Asia	12,32	13,00	13,20	13,50	13,70	14,10	14,50
Europe	13,10	13,90	14,50	15,20	15,80	16,30	16,80
All developed economies	35,36	34,78	36,04	37,99	39,25	40,28	41,30
All developing economies	25,08	26,60	27,70	29,00	30,10	31,50	32,90
World total	60,44	61,38	63,74	66,99	69,35	71,78	74,20

Source: Based on paper of the UNIDO, FAO, World Bank Working Group
on Fertilizers July 1983

The extension of the ammonia capacity is under way in Africa, Latin America, Near and Far East, as well as in the USSR and in Eastern Europe. For example, Algeria is making large investments for the expansion of their ammonia capacity, which in 1985/86 will be 815 thousand tons N. New plants, each with a capacity of 1000 tons/day ammonia are constructed or planned in Morocco, Nigeria, Tanzania and Tunesia. They are supposed to come into operation after 1986.

A large expansion of ammonia capacity is carried out in Mexico, Brazil and in Bahrain, Kuwait, Libya, Saudi Arabia, Turkey, India, Indonesia, Pakistan and Malaysia. Large scale ammonia units of 1000 tons/day capacity are being built in all these countries, basing on captive low cost feedstock (natural gas).

In the USSR new ammonia plants will add over 5 million and in China over 2 million tons of nitrogen in the years 1981-86.

On a world scale, about 56 million tons of ammonia capacity has been added in the period 1975-86.

At the same time some ammonia capacities in the United States, in Western Europe and in Japan are closed down or idled. Nevertheless, the nitrogen production in these countries is not declining, because of the substitution in ammonia imports.

As already mentioned, there is a growing trade in ammonia for fertilizers, with ammonia being shipped from where it is produced to other locations where it is processed. The closure of some ammonia capacities linked to the rationalizing the nitrogen industry. Ammonia and urea plants are closed because of increasing prices for feedstock (naphta), erosion of the competitive position and the loss of export markets.

With all these changes, ammonia capacity, which at the beginning of the 1980's was around 90-91 million tons nitrogen, will increase up to the year 1987/88 to 120 million tons. Although, there is no information available about ammonia capacity development for the beginning of the next decade, it is evident that to satisfy the demand in ammonia evaluated at 90-92 million tons of nitrogen at the beginning of the 1990's about 20-25 million tons N capacity of ammonia ought to be built between 1986-1991.

The Table 2-10 shows the demand/supply balance of nitrogen fertilizers can be expected during the 1980's.

Table 2-10 World N fertilizer capacity, supply capability, demand and balance 1981/82-1987/88

/million tons of N/

	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88
Capacity	100,8	103,8	108,8	113,8	117,1	118,9	120,2
Supply	62,5	62,4	67,5	70,7	73,2	74,8	75,7
Demand	60,4	61,4	63,7	67,0	69,4	71,8	74,2
Surplus	2,1	10	3,8	3,7	3,8	3,0	1,5
Deficit (-)							

Source: Based on paper of the UNIDO /FAO/ World Bank Working Group on Fertilizers July 1983

It can be seen from Table 2-5 how little additional ammonia capacity is introduced by developed market economies. This trend is supposed to continue and to become even more expressed in the future. It can be expected that the increase in demand in North America, Western Europe and Japan will exceed the increase in supply capability.

More new ammonia plants will be built in countries and locations where natural gas, at low cost, is available. This is the case in such countries as Mexico, Trinidad, Algeria, Nigeria, Libya, the Near East countries, Bangladesh, Thailand, Malaysia and Indonesia. The USSR will also become increasingly important as a source of ammonia and nitrogen supply. Part of the USSR production has been already contracted to the United States and to Western Europe on buy-back basis deals in exchange arrangements for plants provided by contractors. The Near East countries where a great amount of natural gas is being flared, and where the investment in infrastructure has been considerably advanced, will also become an important supplier of ammonia and nitrogen products.

Ammonia trade, however, remains restricted by the fact that ammonia import is not useful to those countries which have downstream capacity for urea, since urea cannot be made from purchased ammonia without carbon dioxide a by-product of ammonia production.

A lot of new ammonia/nitrogen plants will be built in large scale capacity units (1000 tpd or more). However, at least 20 per cent of needed additional capacity, between 1986-1991, i.e. around 5 million tons of nitrogen in ammonia, might be established as mini-fertilizer plants, taking technical, economic or other advantages reviewed in Chapter 3.2.

2.3.1.2 Phosphate fertilizer

The average growth rate of phosphate fertilizer demand is expected to be 3.6 per cent annually up to the year 1987/88.

The world demand which was 30.9 million tons P_2O_5 in 1981/82 is expected to increase to 38.2 million tons in 1987/88 (Table 2-11).

Table 2-11 Demand forecast for P_2O_5 fertilizer

/million tons of P_2O_5/

	1981/82 /actual/	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88
Developed market economies	12,74	12,03	12,68	13,49	14,00	14,37	14,74
North America	5,01	4,50	4,80	5,30	5,64	5,80	5,96
West Europe	5,31	5,26	5,55	5,78	5,89	6,01	6,13
Oceania	1,15	1,04	1,08	1,13	1,17	1,22	1,28
Others	1,27	1,23	1,25	1,28	1,30	1,34	1,37
Developing market economies	6,11	6,28	6,77	7,25	7,73	8,33	8,99
Africa	0,55	0,50	0,55	0,58	0,62	0,64	0,71
Latin America	2,18	2,14	2,29	2,44	2,58	2,84	3,10
Near East	1,05	1,14	1,23	1,33	1,43	1,55	1,68
Far East	2,33	2,50	2,70	2,90	3,10	3,30	3,50
Centrally planned economies	12,06	12,60	13,04	13,40	13,76	14,11	14,47
Asia	3,10	3,28	3,47	3,58	3,69	3,80	3,92
Europe	8,96	9,32	9,57	9,82	10,07	10,31	10,55
All developed economies	21,70	21,35	22,25	23,31	24,07	24,68	25,29
All developing economies	9,21	9,56	10,24	10,83	11,42	12,13	12,91
World total	30,91	30,91	32,49	34,14	35,49	36,81	38,20

Source: Based on paper of the UNIDO, FAO, World Bank Working Group on Fertilizers July 1983

According to the FAO/UNIDO/World Bank Working Group on Fertilizers, phosphoric acid capacities will develop substantially in the 1980's. The capacity of this product in 1987/88 will reach 37.7 million tons P_2O_5 compared to 29.66 million tons in 1981/82.

Phosphoric acid is the intermediate for all types of high analysis phosphate fertilizers, such as triple superphosphate (TSP) and ammonium phosphates (DAP and MAP). Production of single superphosphate (SSP) and some marginal product (e.g. ground phosphate rock, basic slag, etc.) accounting for about 10-12 per cent of the total phosphate fertilizer is complementary to phosphoric acid based fertilizers. The production of phosphate fertilizers, the use of phosphoric acid and other high analysis fertilizers increase because of their cost advantage. In 1977 approximately 60 per cent of all P_2O_5 was applied in high analysis fertilizers, by 1990 this will increase to 70 per cent, particularly if phosphoric acid and its derivatives are taking momentum in several developing countries. New large scale capacities are being erected or planned in Morocco, Tunisia, Senegal, Togo, Jordan, Peru, Iraq, Indonesia, etc. Assuming favourable economic conditions they will be sufficient to cover the world demand up to the year 1988/89.

The share of the developing countries in phosphoric acid capacity which is about 19 per cent in 1981/82 will be in 1987/88 about 29 per cent.

The export availablity of phosphate fertilizers is expected to grow as these new capacities are located near phosphate rock supplies. World trade in phosphoric fertilizers will be expected to increase from 4 million tons in 1979 to 10 million tons in 1990. North America will continue to be the leading exporter but Africa will increase its share of the total.

2.3.1.3 Potash fertilizer

The world potash fertilizer demand will increase from 23.9 million tons actual consumption in 1981/82 to 29.7 million tons K_2O in 1987/88 (Table 2-12) and the annual growth rate is expected to be 3.7 per cent up to 1987/88.

The development of production will be continued in countries with rich natural deposits such Canada, U.S.A., USSR, Spain, Israel, and the German Democratic Republic. Also Jordan and Brazil, with investments being underway, will join the producer list.

In some countries, e.g. France, Germany FR, U.S.A. some old potash mines will be closed and the total capacity of the country diminished.

Table 2-12 Demand forecast for K_2O fertilizer

/million tons of P_2O_5/

	1981/82 /actual/	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88
Developed market economies	11,64	11,08	11,71	12,28	12,83	13,15	13,51
North America	5,43	4,62	5,24	5,69	6,14	6,34	6,58
West Europe	5,24	5,25	5,39	5,47	5,55	5,65	5,75
Oceania	0,25	0,25	0,26	0,26	0,27	0,28	0,29
Others	0,72	0,76	0,82	0,86	0,87	0,88	0,89
Developing market economies	3,03	3,19	3,41	3,70	3,90	4,21	4,42
Africa	0,27	0,28	0,30	0,32	0,34	0,36	0,38
Latin America	1,32	1,45	1,56	1,72	1,81	1,99	2,10
Near East	0,06	0,06	0,06	0,07	0,07	0,08	0,08
Far East	1,38	1,40	1,49	1,59	1,68	1,78	1,86
Centrally planned economies	9,26	9,50	9,96	10,36	10,82	11,28	11,74
Asia	0,80	0,70	0,81	0,86	0,92	0,98	1,04
Europe	8,46	8,80	9,15	9,50	9,90	10,30	10,70
All developed economies	20,10	19,88	20,86	21,78	22,73	23,45	24,21
All developing economies	3,83	3,89	4,22	4,56	4,82	5,19	5,46
World total	23,93	23,77	25,08	26,34	27,55	28,64	29,67

Source: Based on paper of the UNIDO, FAO, World Bank Working Group on Fertilizers, July 1983

2.3.2 Major technological development in the future

There is a steady process of improvements in fertilizer chemicals and final fertilizer technologies and this is likely to continue as energy costs rise.

The details of the improvement trends are described in Chapter 3.

2.3.3 Structural development

Energy cost, inflation and raw material prices will be the major pressures faced by world fertilizer producers, primarily in the U.S.A., West Europe and Japan. In this connection the advantage has been moving to fertilizer plants located adjacent to cheap feedstock, although some of this advantage is being lost due to higher capital/operating costs and escalating freight costs. The natural resource availability is becoming the prime determinant in project determination.

Many of the traditional fertilizer producers in the developed countries, most of all those processing imported raw materials, are losing their leading position in the fertilizer trade. Increased ammonia output in Mexico and Trinidad will penetrate the U.S. market, where local production will no longer be competitive with imported products.

Important ammonia/nitrogen production centres, many of them export oriented, are appearing in Africa, the Near East and Asia. The production, based on domestic natural gas of Algeria, Libya, Nigeria, Tanzania, Kuwait, Bahrain, Qatar, Saudi Arabia, Bangladesh, Thailand, Malaysia, Indonesia, etc., will supply not only the nearby markets but also developed countries in Europe and/or Asia.

A similar role will be played by the development of the phosphoric acid and phosphate fertilizer industry in Morocco, Tunesia, Senegal and Togo, although the U.S.A. will continue to maintain a competitive cost position in the world phosphate trade due to its abundant natural phosphate resources.

As for potash, the U.S.A. has long lost its self-sufficiency and is dependent on Canada and other countries for about three-fourths of its agricultural requirements.

Substantial structural changes will take place within the production structure of the fertilizer industry in developed countries. Present plants, particularly ammonia units, will be further modified and old plants that cannot be modified will close.

A new generation of thermally efficient plants will start to appear in the 1980's, due to the need of conserving energy, hence, to produce ammonia at a more economically attractive level. With the increasing imports of phosphoric acid or phosphate fertilizers many sulphuric acid plants are expected to shut down, although the by--product capacity is expected to continue to grow, because of restrictions on SO_2 emissions.

3. DEFINITION AND MAIN CHARACTERISTIC OF THE MINI-FERTILIZER PLANTS

3.1 Introduction

The size of capacity has been steadily going-up over the last few decades. The main reason for this has been the economy of scale, but in case of ammonia a breakthrough in technology has played an important role, too.

Many of the modern fertilizer plants have very large size. These sizes have been reached gradually, thanks to continuous improvements in technology allowing increasing scale economies due to the fact that investments increase less than proportionally to capacities. A large size unit is chosen particularly for export oriented plants. However, problems during the distribution phase arise particularly in the developing countries due to the lack of infrastructure in agricultural areas where fertilizers are consumed. These problems are bound to increase in the future, considering the increasing amount of fertilizer.

Recently a new philosophy has been introduced concerning the possibility to locate several small plants up (e.g. 100-200 tpd ammonia) near the various centres of consumption regions rather than a large unit installed centrally. This can be important for the countries that have sources of raw materials such as small fields of natural gas, oil or coal spread throughout the country.

In this connection it is suitable to think to set of small size fertilizer plant located near to the source and, possibly, in the middle of an agriculture region instead of very large plants located in an industrial area.

As for the ammonia capacity, in the last 15 years the processes have been developed and gradually improved by steam reforming of natural gas and naphta in plants using centrifugal compressors. Standard designs have evolved for three capacities: 550-600, 1000 and 1350 tpd. The great majority of new plants built in the last ten years have been designed for one of these three units. The large size unit is sometimes used in locations where site development costs are high.

For constructing of smaller ammonia plants, China has a wide-range experience. For more than two decades over 1300 small scale nitrogenous fertilizer plants have been built, each producing 5000-20000 tpy of ammonia, and in most cases using anthracite as raw material. There were more than 1300 such plants in operation in 1980 and they have supplied about 55 % of the total ammonia production in China in that year. Besides, China has imported thirteen 1000 tpd units from abroad since the beginning of the seventies.

An engineering firm's data can be also cited by way of illustration. Ammonia Casale SA (Switzerland) has built more than 200 ammonia units during the course of its sixty years' activity in this field, varying in capacity between 10-1000 tpd, for a total of more than 20000 tpd. During the last fifteen years the firm has been established 18 ammonia units in developed and developing areas. Ten of them can be classified into the small-scale category (not more than 250 tpd of ammonia) and three of them are large tonnage units, each has a capacity of 1000 tpd ammonia.

In pursuance with the next list, according to data of Snamprogetti (Italy) having wide experiences in urea technology, the firm has built some small-scale urea plants with capacities ranging from 100 tpd to 300 tpd.

Location	Capacity tpd urea	Start up
Italy	70	1966
Italy	300	1971
Spain	300	1971
USA (Texas)	227	1980
Somalia	150	under construction
–	100	feasibility stage
–	260	feasibility stage

As shown from this list the locations are not concentrated in a typical area, but spread over several regions of the world. This means that trend is generalized and not only the result of particular and local conditions.

In the Table 3.1-1 the ammonia capacities of the world by main regions is shown dividing them into three ranges: small, medium and large-scale units.

Table 3.1-1

Number of ammonia plants

(1977)

Region	Capacity (1000 tpy N) 10-100	100-250	250-500	Total	Total capacity 1000 tpy N
	number of plants				
North America	45	31	25	101	15 950
Latin America	16	4	5	25	2 733
West Europe	36	23	24	83	14 516
East Europe	47	67	24	138	21 578
Japan	9	7	6	22	3 671
China (1980)	1400	8	13	1421	12 000
Rest of Pacific	20	8	0	28	1 840
Indian Sub-Continent	13	16	2	31	4 138
Middle East	6	6	2	14	2 012
Africa	5	4	1	10	778
TOTAL	1597	174	102	1873	79 216

Source: "Market Study of Mini-fertilizer Plants for Developing Countries".
Prepared for UNIDO by Shu Lin Peng,
Sept. 1982

From the data in Table 3.1-1 it can be seen that an overwhelming number falls under the small-scale category. This is a result of the special development tendency in China. Excluding the plants located in China, it can be seen that a lot of small-scale units are in operation but they were built in the 1950's. Since the beginning of the 1960's the capacity sizes have been increasing. As for the highest capacities, many of them have been established in developed areas, many times explicitly for export purposes.

In the phosphate fertilizer industry prior to the decade of 1950's the single superphosphate was the principal phosphate fertilizer all over the world. Later the more concentrated phosphate fertilizers became attractive. They requires phosphoric acid and therefore, the phosphoric acid becomes the principal intermediate raw material of phosphate fertilizer production, playing almost such a role in this field (industry) as the ammonia in the nitrogen fertilizer production.

It makes a good case for that in the past few years phosphoric acid has been the source of perhaps 90 % of the phosphate fertilizer production from new capacities and this trend is expected to continue in the foreseeable future.

The history of the phosphoric acid production by wet-process shows a rapid increase in plant size. Plants built in the United States in the period 1915-1930 had capacities ranging from 7 to 35 tpd. In the 1930's with the introduction of slurry-recirculation system and continuous filtration, the unit-capacity increased to over 90 tpd P_2O_5. In 1960 s the capacity size has reached 600 tpd P_2O_5 and later, by the beginning of 1980's, 1000 tpd P_2O_5 in a single stream.

In Japan where many small phosphoric acid plants are still in operation there are 23 phosphoric acid plants. 17 of them have capacities less than 100 tpd and eight of them are under 60 tpd P_2O_5.

According to a reference list of Nissan Chemical Industries Ltd., the firm licensed about 33 of its own process all over the world. Half of them can be classified into the small-scale category (not more than 200 tpd P_2O_5) and ten of them are under or equal to 100 tpd P_2O_5.

Table 3.1-2 shows the existing phosphoric acid capacity in major regions of the world.

The large scale units tend to be located near the phosphate rock mines, but in some cases near to source of sulphuric acid. The majority of phosphoric acid plants are integrated into downstream fertilizer complexes and there are instances where phosphoric acid plants are built exclusively for international trade.

Table 3.1-2

Number of existing phosphoric acid plants
(1982)

Region	Capacity (1000 tpy P_2O_5)		
	less than 100	more than 100	total capacity
North America	18	43	11 200
Latin America	10	6	1 500
West Europe	49	14	4 360
East Europe	17	33	6 600
Oceania	7	0	290
North-West Africa	6	12	2 640
Rest of Africa	10	4	1 070
Near East	9	6	1 600
South Asia	14	2	790
South East Asia	24	3	1 300
TOTAL	164	123	31 350

Source: "Market Study of Mini-fertilizer Plants for
Developing Countries"
Prepared for UNIDO by Shu Lin Peng,
Sept. 1982.

Both large-scale and mini units will be established in the foreseeable future, depending on the local circumstances, not only in global dimensions but in a number of countries where the production both on mini-scale and large tonnage

will be effective.

Some constraints that is to be considered in decisions prior to setting up mini-plants are:

- **a local market that would be difficult to supply from a larger but at longer distant plant,**
- **a limited supply of raw material(s) at a favourable cost and, possibly, not far from an agricultural area,**
- **severe local conditions e.g. for transporting large, heavy equipment,**
- **a small unit can be conceived with simplified and standard process flowsheet, therefore, it is better suited to a region not duly industrialized.**

3.2 Nitrogen fertilizers

Ammonia - being by itself an applicable nitrogen fertilizer - is the basic material for all commercial nitrogen fertilizers. However, in the agriculture of developing countries only solid products can be considered. The main types are:

Type	Grade (%) N - P_2O_5 - K_2O
Ammonium Nitrate (AN)	34-0-0
Urea (U)	46-0-0
Ammonium bicarbonate	17-0-0
Ammonium Sulphate (AS)	21-0-0

The principal solid nitrogen fertilizers are ammonium sulphate, ammonium nitrate, urea. Ammonium sulphate is the easiest of the above three to store and handle, and it has the advantage of containing sulphur which is also a plant nutrient. But it has disadvantages: its low nitrogen content and high acidifying effects. However, because of its acid reaction in the soil, together with its sulphur content, it is still preferred in some alkaline soils and for some crops e.g. tea.

Ammonium nitrate requires strict attention to safety precautions in its manufacture, handling and storage, because it supports combustion and there is, therefore, a fire risk, and under extreme conditions it can act as an explosive. Partly for this reasons it is often sold with limestone as a mixture, so called "calcium ammonium nitrate" containing 26-28 per cent N. It is well suited e.g. for wheat and it is preferred in colder climates of Europe and North America.

Urea is free from these hazards. It has some tendency to cake in storage but this can be overcome by suitable treatment and by control of storage conditions. Although agronomically it is a little bit less suitable than AN because of its volatilisation characteristics that highly varies depending on soil conditions, urea has nevertheless become the predominant nitrogen fertilizer. The reason is very simple. The main factor determining the share of the market obtained by each product would be the cost per ton of nitrogen applied to the soil.

Ammonium bicarbonate is very volatile hygroscopic and caking, can be stored only in double-walled bags. Nitrogen loss in application can be high. It is used as fertilizer in the People's Republic of China only and no experience is available on its applicability in other countries.

3.2.1 Ammonia

Manufacturing of ammonia needs large investments and the energy consumption is also very high. The productions cost of ammonia is a decisive factor in the production of all nitrogen fertilizers.

The economy of the ammonia synthesis of the early 1960's was possible due to the reasonable selection of the raw material used for ammonia synthesis gas production and the technology applied as well as the increasing the unit-capacity of the production line.

By the beginning of the 1970's ammonia production with small unit-capacity based on coal (coke) as raw material and atmospherical gasification, gave way to plants of high capacity, based on steam reforming of natural gas or higher hydrocarbons under pressure all over the world. The lower capacity limit was set by the minimum capacity of the centrifugal compressors for synthesis gas (600 tpd ammonia unit at that time).

The new process based on hydrocarbon steam reforming is characterized by catalytic gas purification (except for CO_2 removal) and high energy recovery, generating high pressure steam for the process and the turbines of centrifugal machines. Ammonia plants of 1000-1500 tpd capacity were built in developed countries using inexpensive natural gas or straight-run naphta. The ammonia or ready made fertilizer were in great part shipped to markets situated usually far away. Low cost feed-stock, booming fertilizer market, rapidly expanding industrial and economic growth, low cost credits and investment - all contributed to the world-wide concentration of the ammonia production in big units and a highly developed world market. Process technology was adopted to the technical level of the industrialized countries and gradually became more sophisticated. Highest possible temperatures, pressures and severity were aimed at in the reforming, higher possible capacities in the whole line. No wonder that when developing countries having the necessary raw materials followed suite, they ran into troubles. Serious delay and cost overruns in project implementation, low on-stream factors, operational troubles defeated the economic advantages hoped for.

Developing countries having had smaller ammonia plants before and thus possessing enough experienced technical staff and expertise fared much better: when the big units followed the smaller plants more satisfactory records were achieved.

3.2.1.1 The "classic" process of the 1970's

At the end of 1970's and the beginning of the 1980 s the basic technology worked with hydrocarbon feedstock, mainly natural gas. For syn gas production the steam reforming became the most widely used technology. The overall reaction in this process is:

$$CH_4 + 0.3035\ O_2 + 1.131\ N_2 + 1.393\ H_2O \rightleftharpoons CO_2 + 2.262\ NH_3$$

So the minimum stoichiometric consumption of CH_4 is 583 $Nm^3/t\ NH_3$ (4.99 Gcal/t NH_3) and assuming that the totality of the reaction heat can be recovered, the theoretical consumption is 4,45 Gcal/t NH_3 production.

The process is based on pressure steam reforming of natural gas or light hydrocarbons and consists of the following steps:

- Sulphur removal (if necessary)
- steam reforming
- shift conversion
- CO_2 removal
- methanation
- compression
- NH_3 synthesis

In the sulphur removal section the natural gas at medium pressure is treated for removal of sulphur and light molecular weight hydrocarbons by activated carbon and/or catalytic hydrogenation with adsorption on ZnO.

The natural gas mixed with steam is heated and passed through a bed of nickel catalyst in the primary reformer. Here the natural gas is reacted at temperatures of approximately 780-800° C with steam.

The heat necessary to this endothermal reactvions is supplied by external heating. The high temperature flue gases pass through a sophisticated heat recovery system.

In the secondary reforming compressed air is added to provide for the necessary nitrogen in a 3:1 volume ratio and to cover the necessary energy to the completion of reforming reactions by the partial oxidation of the combustable components. The exit hot gases enter a high pressure steam boiler and from it pass to the shift conversion section.

The shift conversion is carried out in two steps:

- high temperature
- low temperature shift conversion in order to arrive at a low (0.1 - 0.3 %) final CO content.

For the CO_2 removal there are numbers of processes available. The three most used systems are based on absorption in water, monoethanolamin or hot potassium carbonate solution.

The final stage is syngas preparation is to remove CO and CO_2 traces. This is accomplished in a methanation unit.

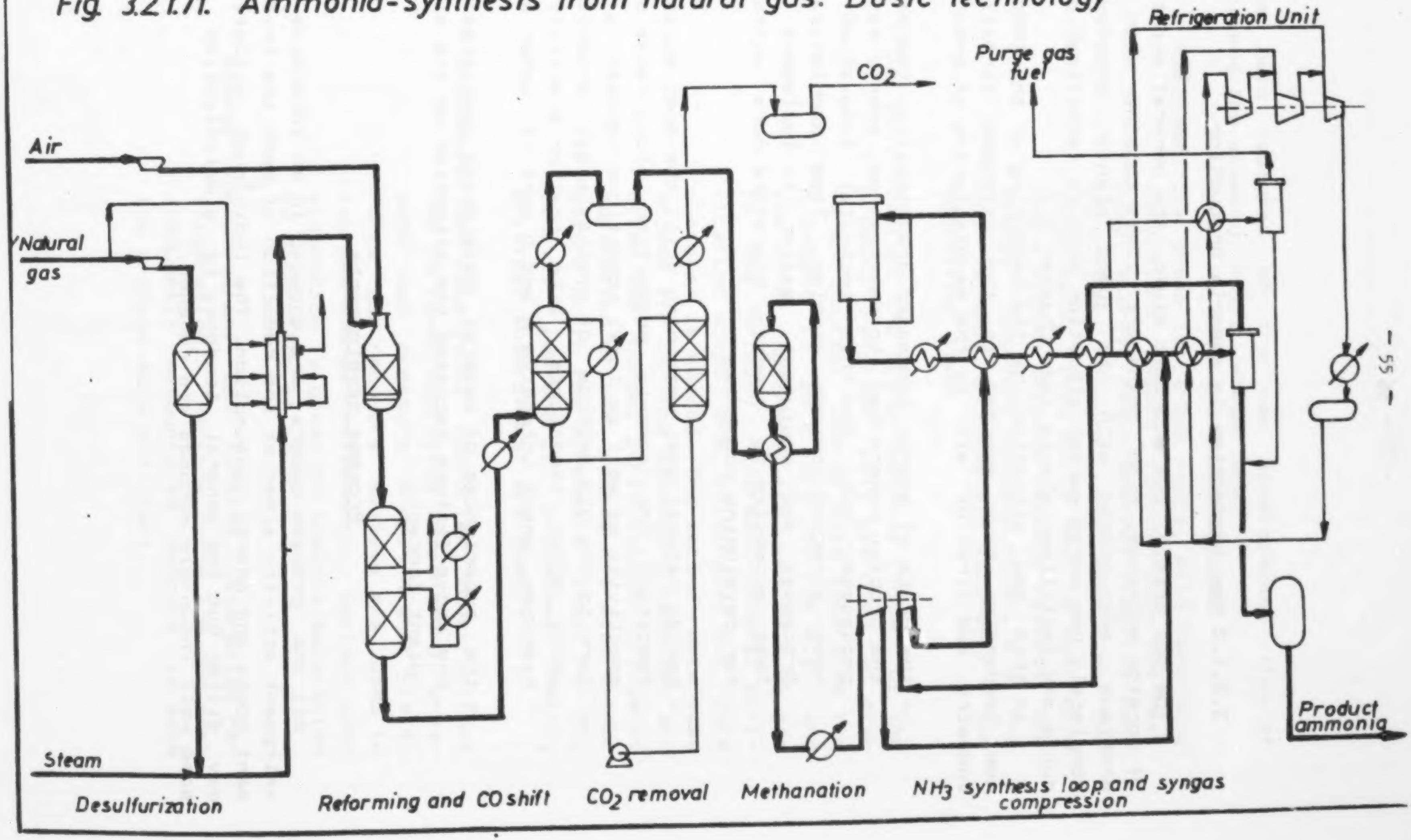
The gas mixture is compressed and enters to the ammonia synthesis sections where ammonia is synthetized.

The product NH_3 is removed from the system by refrigeration. The non converted gas is returned to the synthesis (synthesis loop). Minor part of the gas is continuously purged to remove the inert content of syngas (Ar, CH_4).

The specific energy consumption is 8.5 - 9 Gcal/t NH_3.

The simplified flowsheet can be seen in Fig. 3.2.1/1.

Fig. 3.21./1. Ammonia-synthesis from natural gas. Basic technology


Refrigeration Unit
Purge gas fuel
CO_2
Air
Natural gas
Steam
Product ammonia
Desulfurization
Reforming and CO shift
CO_2 removal
Methanation
NH_3 synthesis loop and syngas compression

3.2.1.2 New tendencies in ammonia production

The oil crisis, the economic slump, the general shortage of foreign exchange, high transport costs together with the problems encountered with the jumbo plants created a completely new world market situation both in fertilizer products and fertilizer plants (see Chapter 2.).

In this new situation, at the beginning of the 1980's, new tendencies have emerged in the nitrogen fertilizer industry and first of all in the manufacturing of ammonia:

- the price of energy increased dramatically, therefore the process owners had to develop new, energy saving processes, but, now this technical innovation has been directed towards simpler, less sophisticated processes and equipment, easier to implement and less expensive to operate, therefore more suitable for developing countries

- beside natural gas, remaining still the most suitable feedstock for ammonia production, long range perspectivity as well as local conditions imposed a return to the old methods of synthesis gas production using other feedstocks, like coal or electrolytic hydrogen, where intensive R and D work is under way

- the experiences of several developing countries and the above factors focussed the attention on the mini--plant concept.

Process developments

All the process owners are engaged in an intensive development activity aimed at the reduction of both the investment costs and energy consumption. The individual situations may differ but the general tendency is simplification and some well known old methods are renewed.

The main features of the new developments (few of them passed the drawing board stage) are:

- Reformer: low steam to carbon ratio, mild reforming conditions reduce considerably the heat load, energy requirements, simplify construction, reduce investment. On the other hand, less waste heat is available and a higher methane leakage results. New energy recovery systems enter, e.g. the new version of the old saturator - dehumidifier loop.

- Gas purification: the higher methane content of the primary reformer exit gas open two different routes: one of them separates the hydrogen in pure form (by PSA e.g.) and the other components are used as fuel gas in the primary reformer. Several purification steps are eliminated but pure nitrogen is needed. The second route uses excess air in the secondary reformer and after the normal purification cryogenic separation of the excess nitrogen either before or in the synthesis loop. For CO_2 removal low-energy processes (mainly physical absorption) are used.

- Synthesis: New catalysts, converter constructions led to lower operating temperature, pressure and pressure drop, higher yield. Purge gas recovery systems are used to improve energy efficiency. Serious consideration is given to ammonia separation by absorption in water.

- Energy conservation: Gas turbine, absorption refrigeration, Rankine cycle are the most frequently encountered methods to make the process more efficient.

As a result of the above general tendencies, several new process schemes have been worked out. All of them are well suited in principle for implementation in the developing countries and particularly for mini-fertilizer plants, but only after having been proven on a commercial scale.

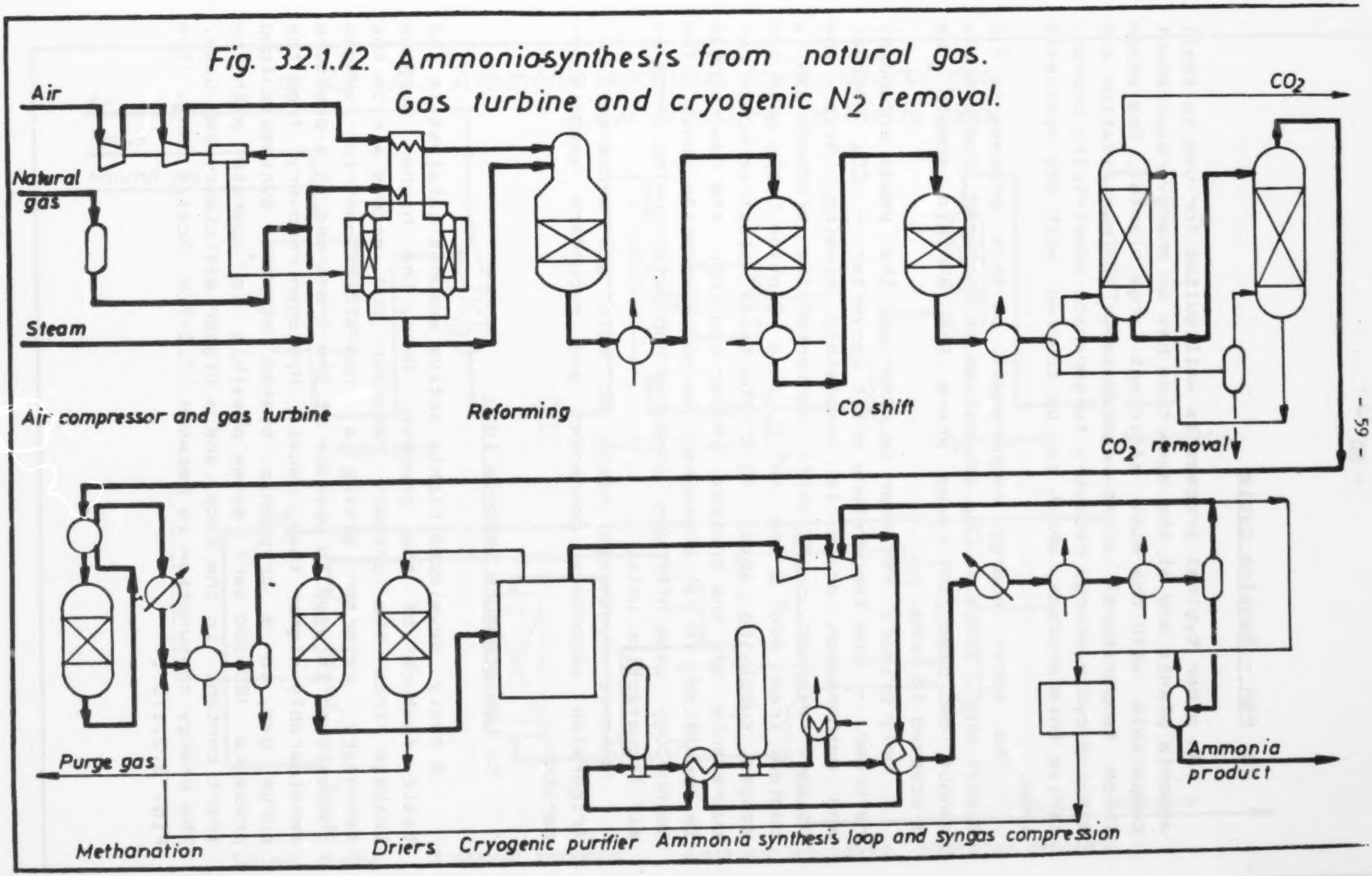
A few typical examples of the proposed flow-sheets are summarized here.

A. Excess air - cryogenic separation - gas turbine

In this process, due to the mild primary reforming, excess air is used in the secondary reformer. This allows the reformer fuel being considerably reduced and the front-end pressure increased.

Further energy saving is achieved by installing a gas turbine driven process air compressor. The oxygen rich exhaust gases are used as combustion air to reformer burners. Nitrogen exceeding the stoichiometric value is extracted in a cryogenic unit downstream of the methanation section. This gives an additional advantage of inert-free syngas (Fig. 3.2.1/2).

Fig. 3.2.1./2. Ammonia-synthesis from natural gas.
Gas turbine and cryogenic N_2 removal.


Air
Natural gas
Steam
CO_2
Air compressor and gas turbine
Reforming
CO shift
CO_2 removal
Purge gas
Ammonia product
Methanation
Driers
Cryogenic purifier
Ammonia synthesis loop and syngas compression

B. PSA - Rankine cycle

An other typical process is well suited for use in small ammonia plants and at the same time has an energy requirement comparable with the most efficient large plants. One stage (high temperature) shift conversion, PSA purification and Rankine cycle energy recovery to generate electricity characterize this process, which can be coupled with any synthesis loop.

The total energy requirement of this process is 7.3 Gcal/t NH_3 . Since no CO_2 separation is included, the process cannot be used in cases where the ammonia should be processed to urea.

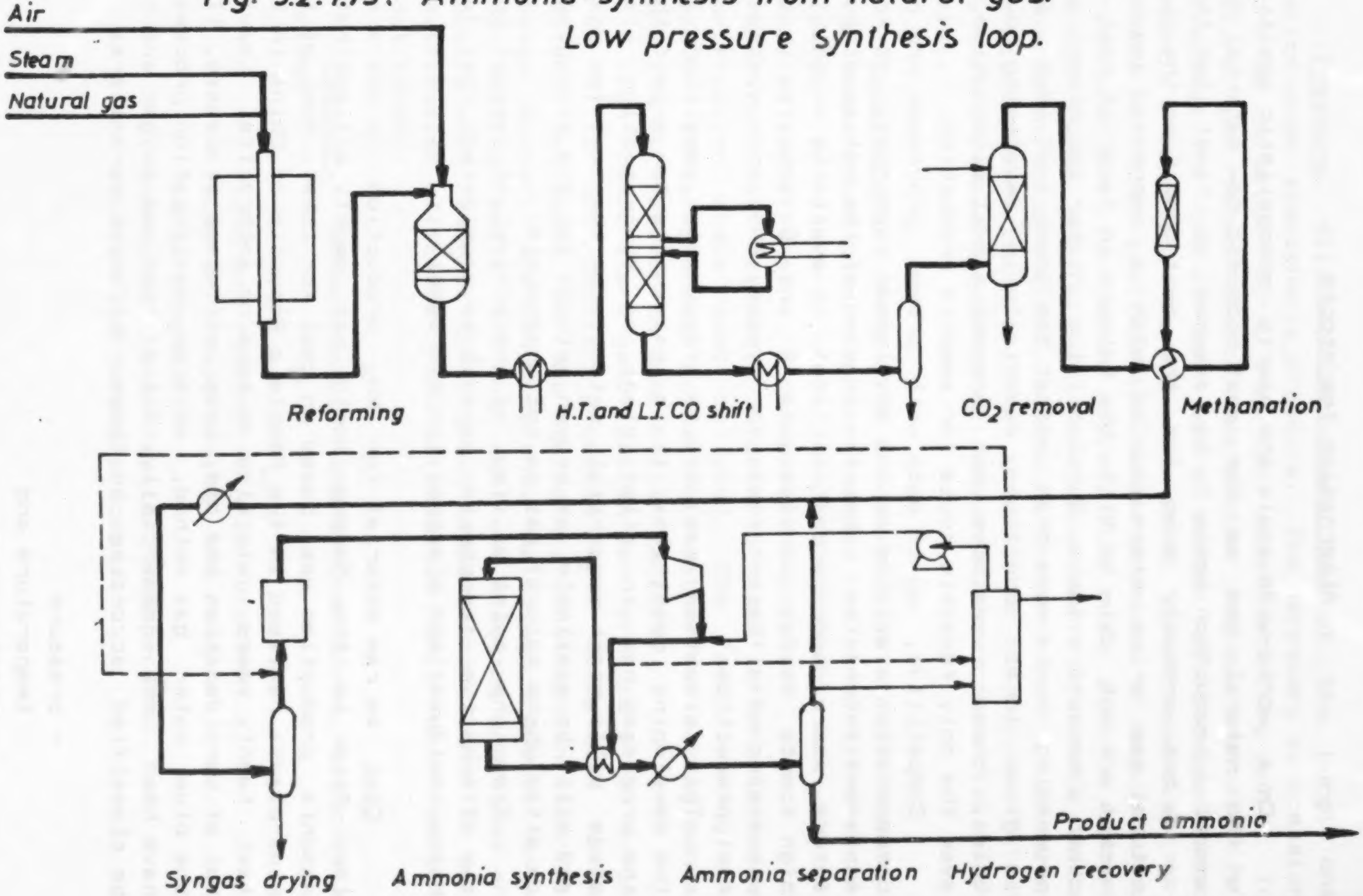
Only primary reformer is used and the usual secondary reformer - low temperature shift converter - CO_2 removal and methanation drain is completely missing. After the primary reformer - HT shift converter the product gas is cooled from 400° C to 64° C in a Rankine Cycle with two stages, supplying about 43 % the total electric power requirements of the process. After cooling, the raw syngas is purified in a pressure swing adsorption unit. The technology uses nitrogen produced on site coming from an air liquefaction unit.

Ammonia synthesis needs no cold gas exchanger, refrigerated secondary condenser and secondary ammonia separator.

C. Low pressure ammonia loop.

A newly developed highly active ammonia catalyst is the basic feature of the process. Here, the higher methane leakage from the primary reformer and excess air in the secondary reformer giving a non-stoichiometric syngas composition is used to operate at the front end at a pressure considerably higher than usual. Hydrogen recovery from the purge gas, in a cryogenic system at the synthesis loop pressure (80-100 bar) makes possible to operate with low inert content in the loop and a higher efficiency per pass. The energy consumption is between 7.2-7.6 Gcal/t NH_3. (See Fig. 3.2.1/3).

Fig. 3.2.1./3. Ammonia-synthesis from natural gas. Low pressure synthesis loop.


Air
Steam
Natural gas
Reforming
H.T. and L.T. CO shift
CO_2 removal
Methanation
Product ammonia
Syngas drying
Ammonia synthesis
Ammonia separation
Hydrogen recovery

Alternative feedstocks

On a world-wide scale the nearly monopolistic position of the natural gas as the most economic raw material for ammonia production seems to be assured at least for this decade but probably even for the next one. Even the high natural gas price rises coupled with a depressed ammonia market are not able to tilt the balance in favor of coal or other alternative fuels. Substantially higher investment and processing costs more than offset the lower fuel costs. But in given local conditions, especially in developing countries, these feedstocks can present a real alternative or even the only feasible route for ammonia production.

Competitive, up to date well proven processes are not commercially available in the developed countries, governments and interested companies in view of the not so distant future where hydrocarbon will not be available or only at high costs deploy considerable R and D activity in the processing of different fuels for syngas, SNG and synthetic fuel production.

This situation can create favourable conditions for the developing countries: it is reasonable to expect that the processes now in pilot plant or demonstration plant stage will reach commercial maturity in the next few years and will be available as proven methods for the mini-plants on sites where natural gas is not accessible.

From the point of view of the mini-plant concept only two alternative feedstocks have to be considered: coal (and heavy residues) and electrolytic hydrogen.

Coal as raw material for NH_3 production is not a new idea. Prior to the Second World War nearly all synthetic ammonia production was based on coal (or coke). Most of the mini-plants realised in the People's Republic of China in the last twenty years rely also on coke or anthracite. Leaving out of consideration the old, less efficient processes, like the blue water gas method, several gasification processes have been used commercially. All of them use oxygen and can be classified according to three different parameters:

- pressure
- temperature and
- reactor type.

Pressure. All old processes, except the Lurgi one worked under atmospheric pressure. The necessary compression work up to around 30-40 bar, the usual starting point in natural gas based plants adds another serious economic disadvantage to the already heavy burden of the coal based ammonic production. Texaco and Shell have commercial processes for the gasification under pressure of heavy fluids (residues) but for solid matter, like coal, even in experimental stage, only slurry (coal suspended in water) can be considered. Nevertheless, intensive research work is going on to adapt other technics like the Winkler and Koppers-Totzek to medium pressure operation. However, no commercial plant exist.

Temperature. Among the processes, low temperature and high temperature ones can be found. Low temperature gasification is easier, needs simpler equipment, but the gas produced contains many inconvenient impurities also a high proportion of methane. Expensive and often corrosive purification steps must be used. The "ash" leaving the reactor contains enough combustible matter for making mandatory its utilization in some boiler facility.

High temperature gasification can produce a raw syngas free of tar and similar products with acceptable methan content, but poses serious equipment, construction material, dosage (burner) and ash problems. Solid ash removal (under the melting point of the ash) and slagging processes are equally used. Even at the highest temperatures (1500° C) good gasification efficiency can be expected only with reactive coal types.

Reactor. Conventionally there are three basic categories:

- fluid bed reactor (Winkler process)
- fixed or slowly moving bed reactor (Lurgi process)
- entrained bed reactor (Koppers-Totzek and Texaco processes).

All processes are heavily dependent on the coal quality. Therefore a general assessement of the individual merits and disadvantages of the different processes would be futile, all the more that all processes are in reality yet in the development stage, even if several of them can refer to realised and operative commercial plants. Therefore in this study no individual description of the different processes will be given. Instead one high temperature entrained fed coal gasification and a heavy oil gasification process will be presented below for illustration only.

High temperature entrained bed coal gasification
(under pressure)

Coal slurry is gasified under pressure (20-100 bar). Typical gas composition from the process:

CO	54 %
H_2	34 %
CO_2	11 %
Others	1 %

The flow diagram of the process is in Fig. 3.2.1/4.

Heavy oil gasification

The flow scheme of the process appears in Fig.3.2.1/5. The preheated oil, oxidant (oxygen or enriched air) and steam are mixed in the combustion chamber and fed into reactor. In the autothermal reactor the partial oxydation of the relevant part of the fuel provides the necessary heat for the reforming and cracking reactions at temperatures 1000° C - 1600° C. The product gas leaving the reactor carries a great amount of sensible heat. Where gasification is performed with oxygen, about 2.8 t of steam are produced in the waste heat boiler for every ton of oil gasified. The carbon content of the crude gas leaving the boiler is eliminated by a special water wash system yielding pumpable carbon slurry and virtually carbon free gas. For further purification to make ammonia syngas the usual adopted process will be adopted.

Fig. 32.1./4. Typical „second generation" coal gasification for ammonia synthesis gas.

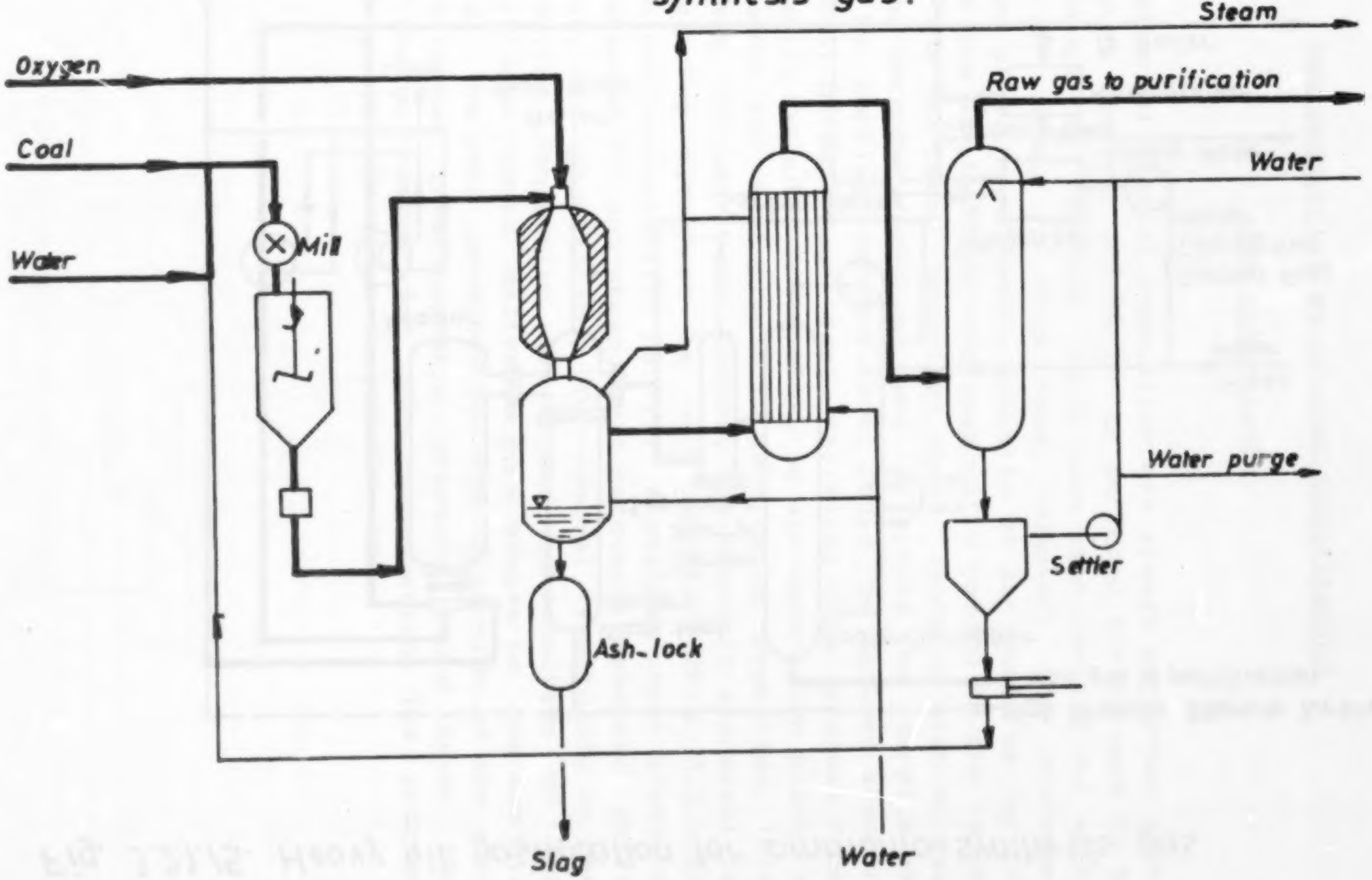
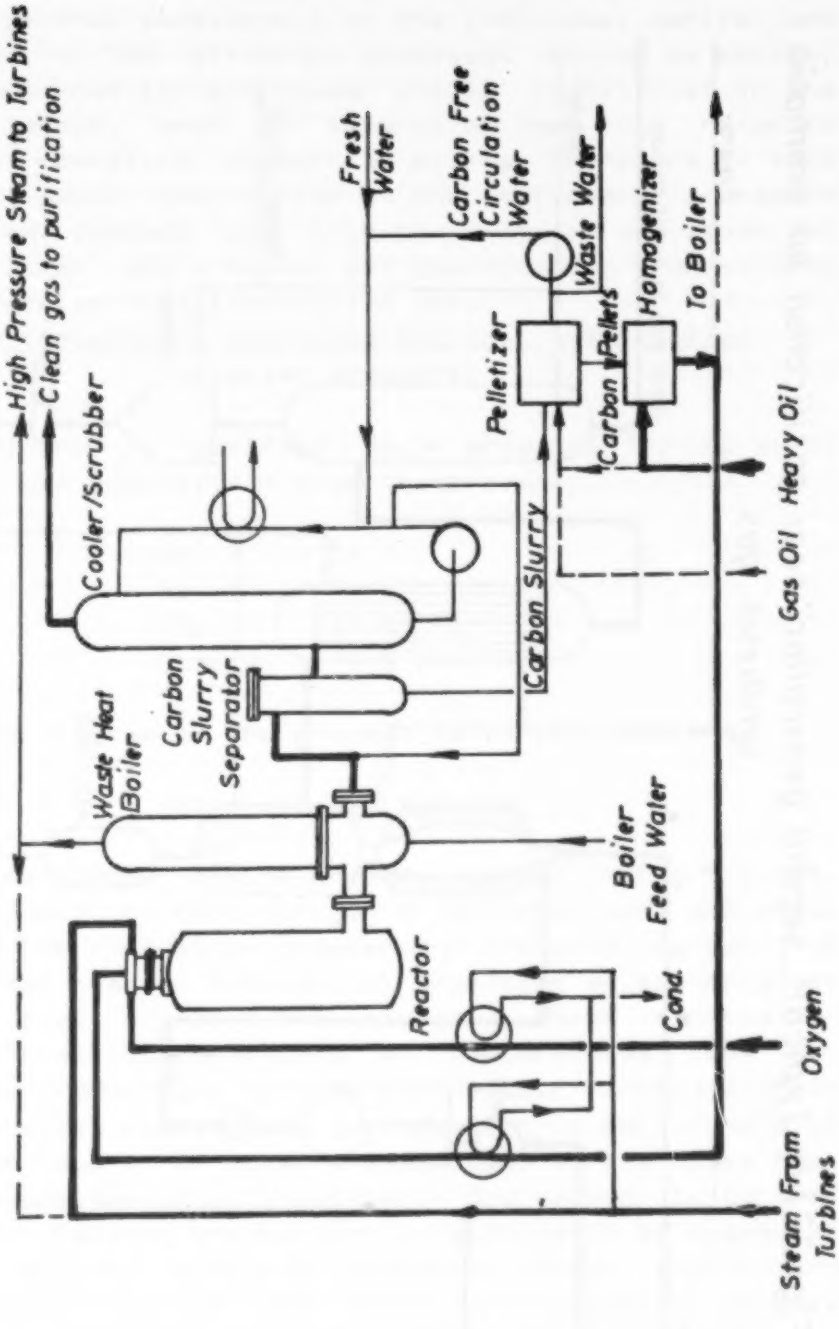

Steam
Oxygen
Raw gas to purification
Coal
Water
Mill
Water
Water purge
Settler
Ash-lock
Slag
Water

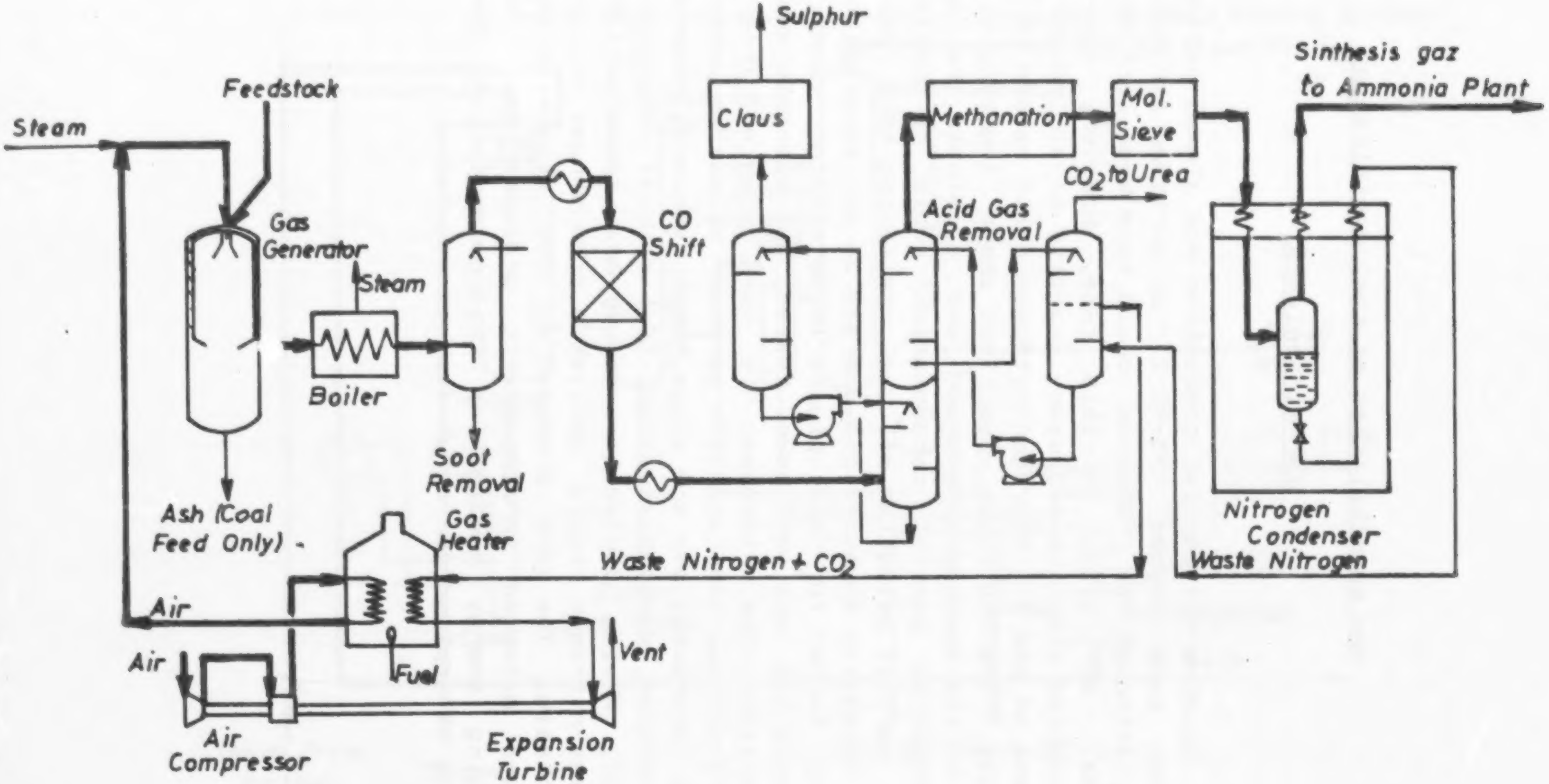
Fig. 3.21./5. Heavy oil gasification for ammonia-synthesis gas.


High Pressure Steam to Turbines
Clean gas to purification
Fresh Water
Carbon Free Circulation Water
Waste Water
Homogenizer
To Boiler
Cooler/Scrubber
Pelletizer
Carbon Pellets
Carbon Slurry
Carbon Slurry Separator
Waste Heat Boiler
Boiler Feed Water
Reactor
Cond.
Oxygen
Steam From Turbines
Gas Oil
Heavy Oil

New possibilities of coal gasification for mini-plants

Autothermal partial combustion was always performed with either pure oxygen (95-98 %) or enriched air (around 50 % O_2), although the reaction could have been carried out with normal air also. In this case, however, the nitrogen introduced with the necessary quantity of air could be far in excess of the 3:1 hydrogen-nitrogen ratio needed in the final syngas. The new ideas described above (working with excess air in the secondary reformer and eliminate the surplus of nitrogen by partial condensation) could be applied also to the partial oxidation of coal, relieving this process from the necessity to build and operate an air separation plant, a heavy burden for mini-plants in developing countries. This process has not yet been tested, but economic appraisal is promising. The flowsheet is very simple: (Fig. 3.2.1/6) entrained bed non-catalytic partial oxydation under pressure with preheated air and steam, heat recovery, removal, shift conversion, desulphurisation, CO_2 removal (eventually in one step), drying (molecular sieve) and condensation of the excess nitrogen could deliver a pure syngas to the ammonia synthesis. The cold produced by the expansion of the condensed nitrogen to atmospheric pressure could cover the cooling energy needed for this condensation. The process could be applied for other feedstocks, too.

Fig. 3.2.1./6. Ammonia-synthesis gas from alternative feedstock by air gasification.


Steam
Feedstock
Gas Generator
Steam
Boiler
Ash (Coal Feed Only) -
Soot Removal
CO Shift
Sulphur
Claus
Acid Gas Removal
Methanation
Mol. Sieve
CO_2 to Urea
Sinthesis gaz to Ammonia Plant
Nitrogen Condenser
Waste Nitrogen
Waste Nitrogen + CO_2
Gas Heater
Air
Air
Fuel
Vent
Air Compressor
Expansion Turbine

Ammonia from electrolytic hydrogen

Water electrolysis as a basis for ammonia production can be compatitive only where abundant and cheap electric power is available.

The nitrogen required is produced by air separation.

Although the hydrogen is very pure, its very small oxygen content has to be removed by means of catalytic combustion.

Comparing to the production of ammonia from hydrocarbon feedstock this route is much simpler and does not contain any complicated process steps operating at high temperatures and pressures - apart from the ammonia synthesis unit, which is the same for all processes. Nevertheless, the investment costs are high. Recent development works on new electrolytic cell types (membrane) are promising: it seems reasonable to expect competitive investment costs in a few years time. On the other hand the very high energy consumption: 10 MWh/t NH_3 will remain in the same region: more than 20-30 % saving seem not possible to achieve. This, calculated with a factor of 2700 kcal/kWh means 27 Gcal/t NH_3, roughly three times more than the value of 8-9 Gcal/t NH_3 usual for nowadays plants.

Electrolysis under pressure, another field of R and D activity would save the energy needed for the compression of hydrogen.

In any case, this process will never be competitive if power is produced in a thermal power plant. Where hydro-electric power is available at low cost due consideration should be given to this alternative. The calculations showed, that only if electric power is available for 3-14 dollar/MWh can this method be competitive.

In this connection, it is necessary to emphasize that an ammonia plant must be built for several decades of operation. In some cases at a remote location a hydroelectric power plant is built and at the beginning no industrial user is there and electrification of the country seems rather remote. In this situation e.g. an ammonia plant is built on cheap electrolytic hydrogen. In a few years time accelerated industrialisation and electrification takes place and a shortage of power results. The newcomers can afford to pay substantially higher prices for the power than the ammonia plant, so this latter either must follow suite and become uncompetitive or bear the cost and inconvenience to convert the plant to some other feedstocks. Several developing countries (e.g. Egypt) had experienced this situation.

Mini ammonia plants

The general situation of world economy, the currency problems, transport costs, experience in developing countries with either jumbo or mini-plants, the recent developments etc., justify to seriously considere the mini-plants as a viable alternative for the developing countries entering in the fertilizer production field.

The concept of mini-plant in the case of ammonia production means today a plant capacity of 100 to 250 tpd, in spite of the fact that these capacities were considered as big units in the 1950's.

The new developments described above are favourable for the mini-plants: higher specific costs would occur if the same flowsheet was used. Simplifications (lower steam pressure, less demanding BFW specifications etc.) can more than offset these higher costs. Reciprocating compressors are more expensive, but have better efficiency. So it became possible to devise new flowsheets for mini-plants having competitive specific parameters with the big plants. These flowsheets will be worked out in detail and proven commercially only if the interested contractors will be persuaded that an adequate market justifies the expenses involved. Nevertheless even now, on the basis of the information gathered it was possible to present two alternatives. The first is presented for a 150 tpd plant, the other for a 250 tpd one. The capacities serve only as examples, since around these values the economics will change only slightly. It must be emphasized, that these are not "chosen" or "recommended" fix capacities, but serve only as examples for the economic calculation. Any other capacity around this values, say between 100 and 350 tpd can be realised. It seems that the first, less efficient (higher energy consumption) flowsheet (the classic one without sophisticated heat recovery system) is more justified for smaller units, while the second, represented on Fig. 3.2.1/7, using many of the new ideas would be more easily adapted to the higher half of the capacity range of mini-plants.

This flowsheet promises better performance than the majority of 1000 tpd plants operating at the moment, in spite of simplified design with saving on erected costs and with all electricity generated internally. The water system is similarly simplified so that water treatment is confined to few grams per day of unexpensive chemicals.

The ammonia plant is designed to use dry natural gas which is heated and desulphurized over zinc oxid catalyst system. Then steam is added to give a molar steam: carbon ratio of about 2.75:1 before entering at 480° C the reformer. Process air without preheating is then added to save heating cost in secondary reformer which is followed by two stages CO shift. The heat available after secondary reformer is used to raise 45 bar steam. For acid gas removal the MEA washing is chosen for excellent performance and for column of moderate dimensions. After compression the methanation of the remaining CO is performed and after cooling the gas is dried before mixing with unconverted loop gas at the entry to the circulator. The ammonia loop is very simple. The converter feed is heated to 255° C before entering a single bed converter.

Heat is recovered as 45 bar steam for hot gases leaving the converter. The cooling, respectively chilling is in two stages to condense out the product ammonia.

The total energy requirement of this process is 8.3 Gcal/t NH_3.

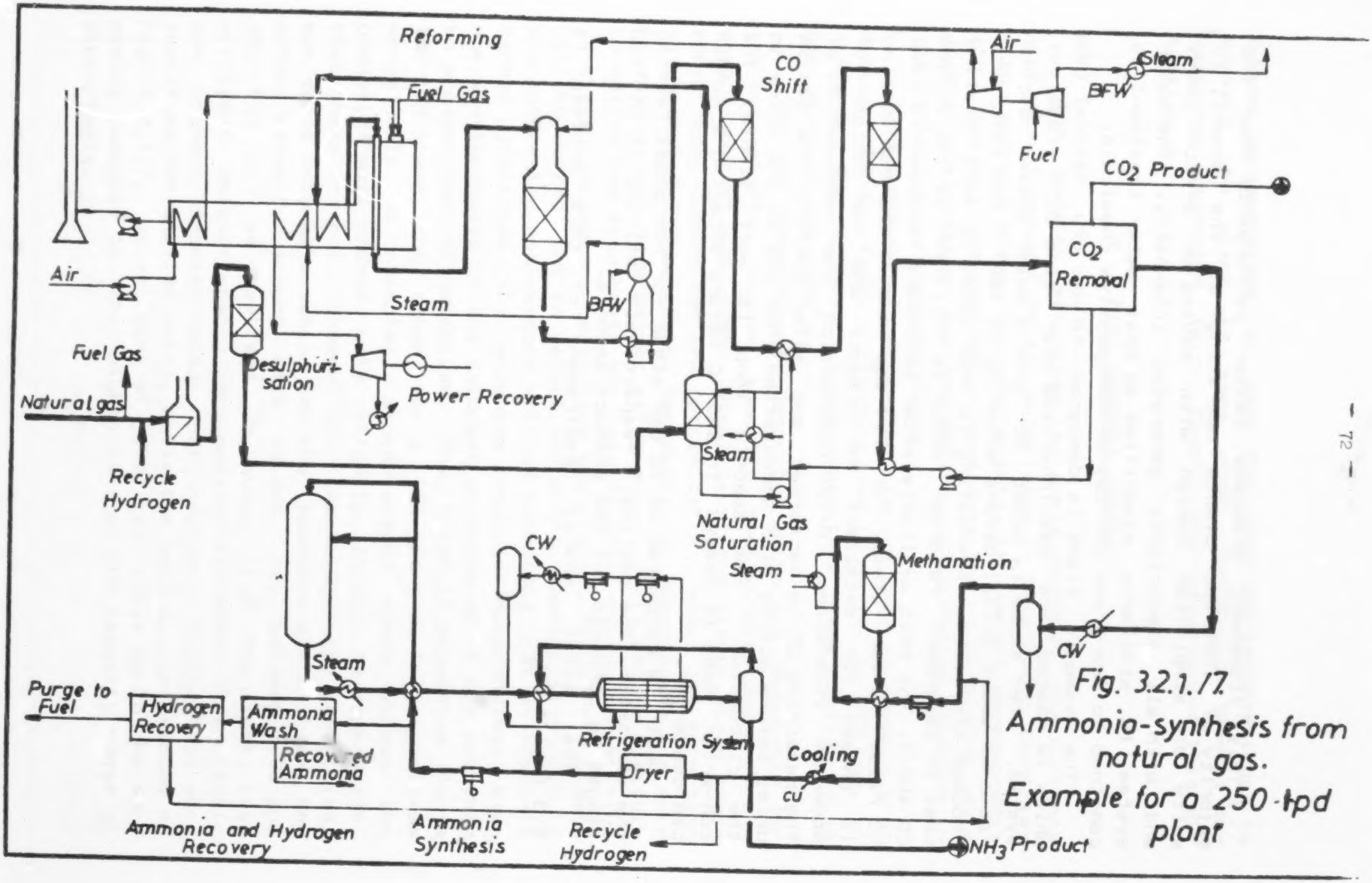

Reforming
Fuel Gas
Air
Fuel Gas
Natural gas
Recycle Hydrogen
Steam
BFW
Desulphuri-sation
Power Recovery
CO Shift
Steam
Natural Gas Saturation
Steam
Air
Fuel
BFW
Steam
CO2 Product
CO2 Removal
Methanation
CW
CW
Steam
Purge to Fuel
Hydrogen Recovery
Ammonia Wash
Recovered Ammonia
Refrigeration System
Dryer
Cooling
cu
Ammonia and Hydrogen Recovery
Ammonia Synthesis
Recycle Hydrogen
NH3 Product

Fig. 3.2.1./7. Ammonia-synthesis from natural gas. Example for a 250-tpd plant

Technical and economic evaluation

In order to assess the competitiveness of the mini-plants, battery limit investment and specific consumption figures were computed, based on the available information for

- three capacities
  - 150 tpd
  - 250 tpd
  - 1000 tpd ammonia

- three feedstocks
  - natural gas
  - fuel oil
  - coal

These values, summarized in the Table 3.2.1-1 served for the economic appraisals.

Using the process data of Table 3.2.1-1 and the method described under Chapter 1.1, the following results were obtained for the ammonia production (Details and calculations can be found in Annex 3/1).

Total investment costs including offsites and the derived total specific investment costs are summarized in Fig. 3.2.1/8 and 3.2.1/9.

Factory gate costs (including 15 % ROI) of ammonia production per ton of NH_3 are presented for the different alternatives in function of the feedstock prices (calculated in Dollar/Gcal) in Fig. 3.2.1/10.

Ammonia cannot be considered as a fertilizer in the developing countries, therefore no price was computed.

Table 3.2.1-1

Battery limit costs and consumption figures for ammonia production /developed site/

Product: Ammonia

Nominal capacity		150 t/d			250 t/d			1000 t/d		
		natural gas	fuel oil	coal	natural gas	fuel oil	coal	natural gas	fuel oil	coal
Battery limit cost	M$	20	23	32	27	31	43	100	115	160
Distribution of investment cost:										
- licence, know-how	%	2	2	2	2	2	2	2	2	2
- engineering	%	16	16	16	16	16	16	16	16	16
- equipment and machinery	%	53	53	53	53	53	53	53	53	53
- civil engineering and erection	%	29	29	29	29	29	29	29	29	29
Materials and Utilities Consumption/t NH_3										
Feed and fuel	10^6 kcal	7,5	7,8	12,0	8,4	8,7	12,8	7,2	8,24	10,3
Power	kWh	885	900	1100	-	-	-	72	80	100
Cooling water	m^3	515	550	800	300	320	345	120	160	171
BFW		1,8	2,0	3,5	1,2	2	3	1,2	2	3
Labour	men/shift	8	10	15	8	11	15	8	10	16

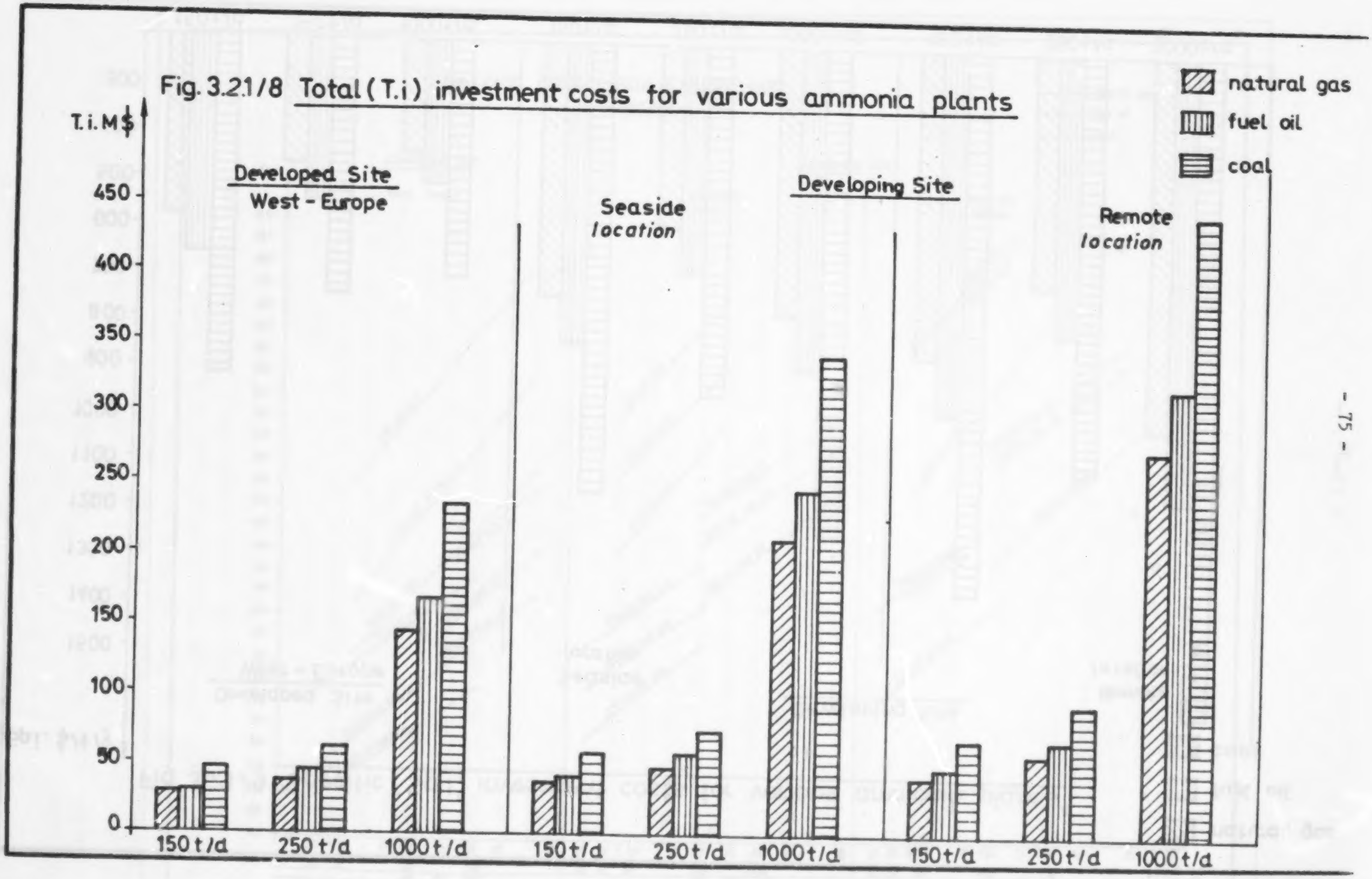


Fig. 3.21/8 Total (T.i) investment costs for various ammonia plants

Fig. 3.21/9 Specific (Sp.i) investment costs for various ammonia plants

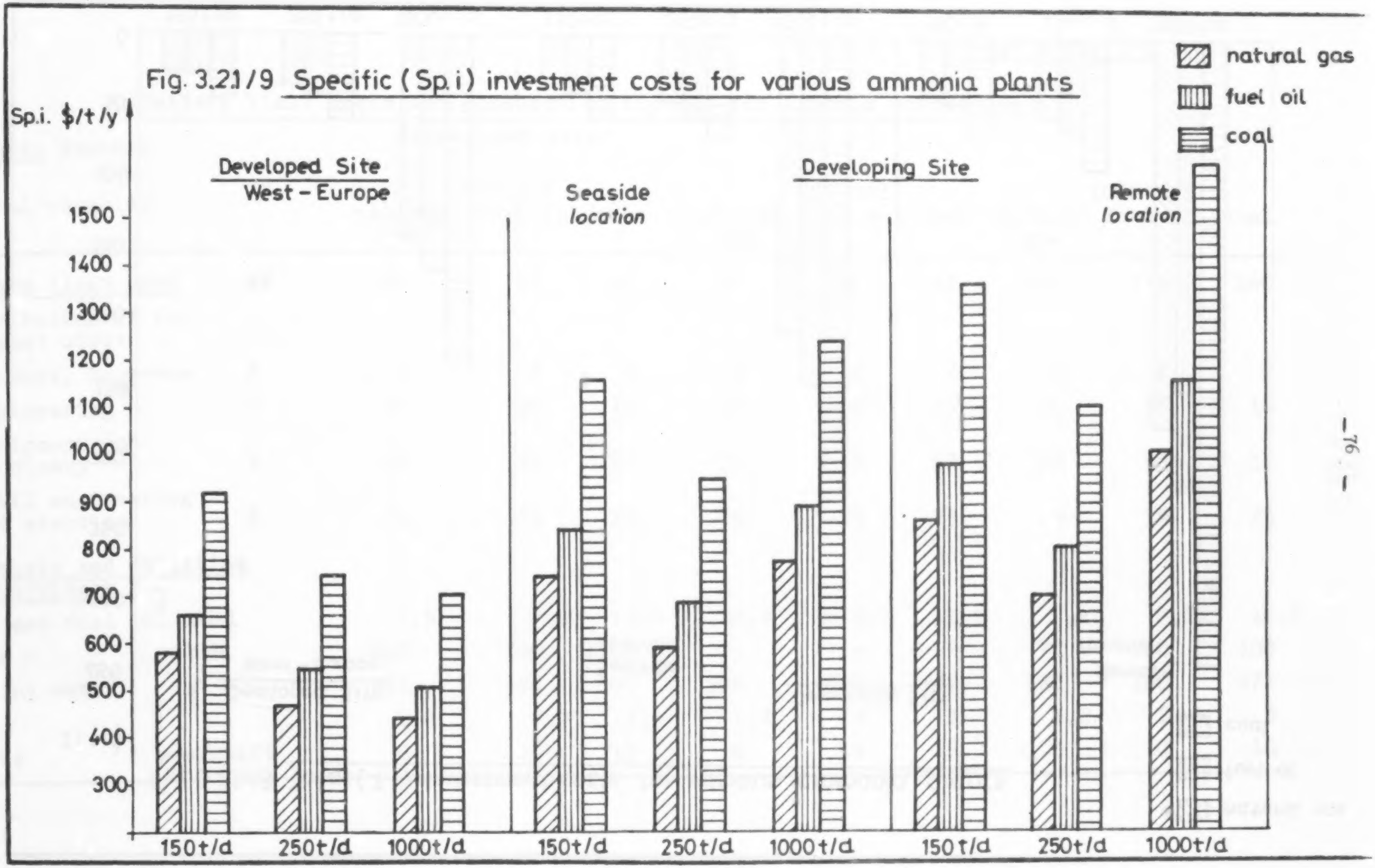
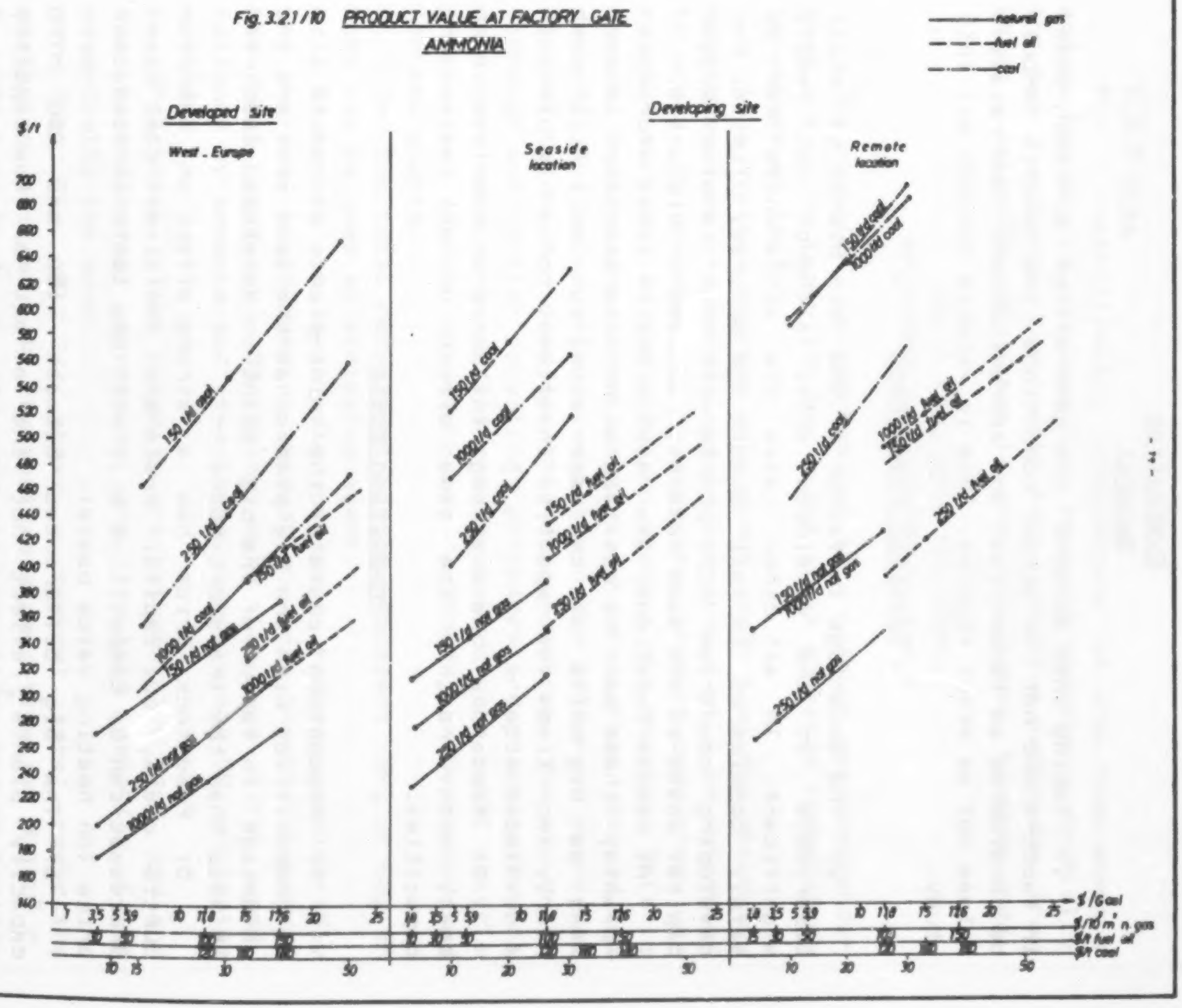


Fig. 3.21/10 PRODUCT VALUE AT FACTORY GATE
AMMONIA



Evaluation

General

1) Taking into account the generalized approach based in factors and not on actual conditions the results should be considered as tendencies and approximations and relative values not as exact figures. This is valable through all this study.

Specific investment

2) The advantage in favour of the big plants is still observable at the developed site, although not really significant. In all other cases the differences can be safely considered to fall within the accuracy limits. For developing countries mini-plants will not involve bigger capital costs as the same capacity realized in big units.

At remote locations, the most probable sites for mini-plants, these can be realised with less specific investment as big units at the same site, but will still cost nearly two times the specific investment of a big plant in a developed site.

3) Feedstock has a strong influence on the investment cost, with roughly the same effect on all sites and capacities.

Production costs

4) Production costs of the mini-plants at remote site is competitive with the big plants at the same site and the advantage in favour of the big plant in developed countries is less than the transport costs.

5) Feedstock price has a strong effect on the production costs, but capital costs are decisive: coal based processes can be competitive only with one tenth of feedstock price (on heating value basis).

6) The big differences between 150 and 250 MTPD capacity plants reflect not the effect of the capacity factor but that of the flowsheet. Many improvements and development introduced into the bigger capacity flowsheet are not considered in the smaller one. It can be supposed, that the smaller plants - if enough demand will justify it - will undergo similar technical improvements and will arrive at nearly the same level of competitiveness as the 250 MTPD plants.

3.2.2 Urea

The industrial-scale manufacture of urea from ammonia and carbon dioxid involves two separate reactions. Initially the two reactants combine to form ammonium carbamate, from which a molecule of water is then eliminated to give urea.

$$CO_2 + 2NH_3 \rightleftharpoons NH_2COONH_4$$
$$NH_2COONH_4 \rightleftharpoons CO(NH_2)_2 + H_2O$$

The reaction is carried out in a reactor operated under pressure - at least 100 bar - and at an elevated temperature in excess of 160° C.

In a typical reactor only about 60-70 % of the stoichiometric mixture of ammonia and carbon dioxid will be converted to urea. It is necessary to separate product urea from unreacted carbamat in the solution leaving the reactor. This is done by decomposing ammonium carbamate to carbon dioxid and ammonia. The main differences between the different processes lies in the method used for this decomposition. The old once--through and partial recycling processes are practically not used any more, only different versions of the total recycle process and mainly the stripping methods can be considered for new plants.

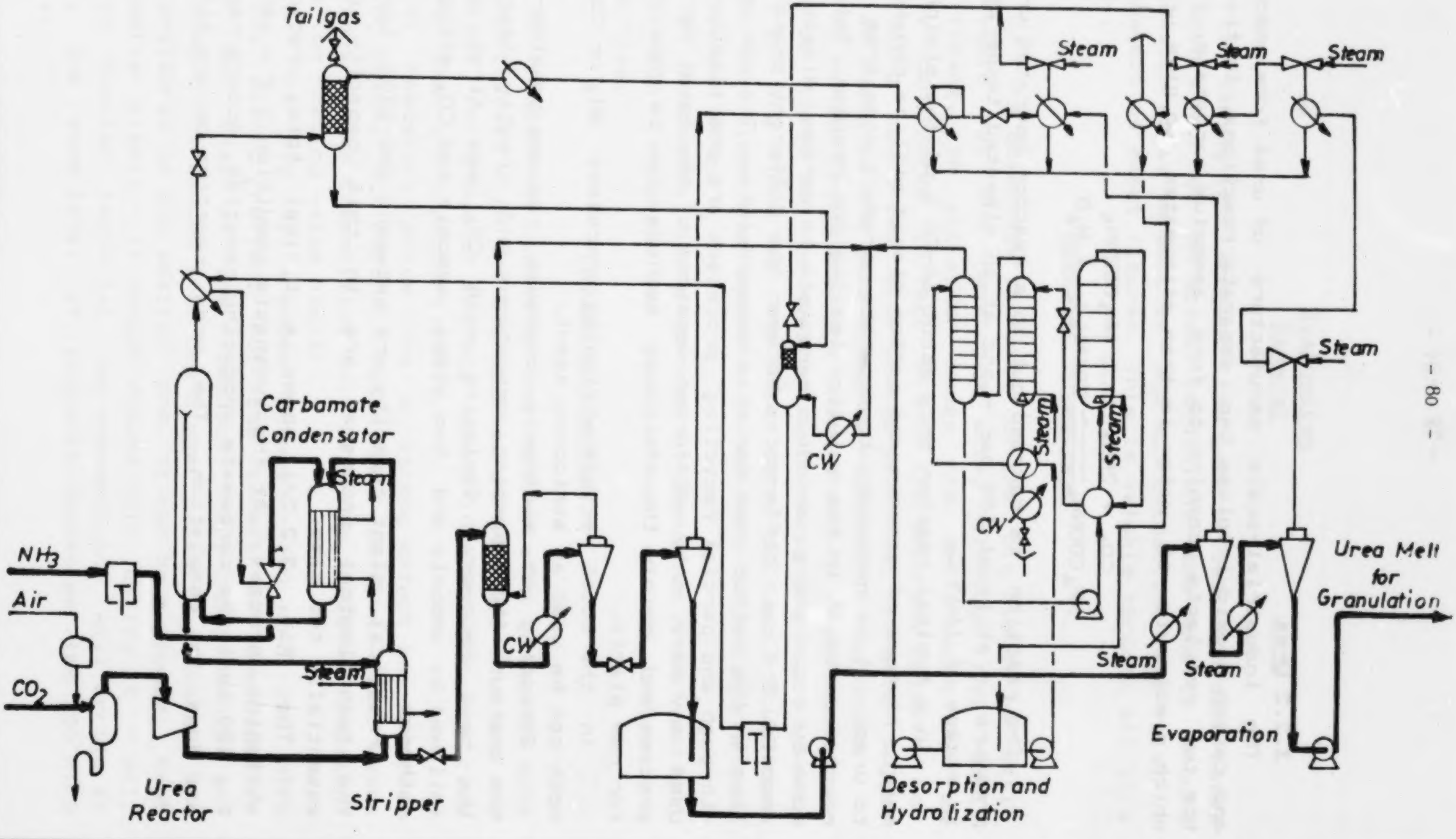
In the total recycle stripping processes NH_3 or CO_2 or both can be used as stripping agent.

Stripping at synthesis pressure reduces considerably the onerous fluid pumping operations and greatly improves the heat recovery. Stripping with CO_2 was first used, followed by ammonia and two steps, ammonia and CO_2 stripping methods.

Practical plant capacity are between 300-1700 tpd and the technological processes are in this capacity range essentially the same.

The Fig. 3.2.2/1 shows a typical total recycling stripping process. At the synthesis condition ($T = 180°$ C, P : 150 bar) the carbamate producing reaction occurs rapidly and does to completion. The urea reaction occurs slowly.

Fig.3.2.2/1. Urea synthesis and Evaporation


Tailgas
Steam
Steam
Steam
Steam
Carbamate Condensator
Steam
NH3
Air
CO2
Steam
CW
CW
Steam
Steam
CW
Urea Melt for Granulation
Steam
Steam
Evaporation
Urea Reactor
Stripper
Desorption and Hydrolization

From the reactor the mixture flows to the steam heated stripper, where, as stripping medium CO_2 is introduced to decompose the unreacted carbamate and the gases are fed to the carbamate condensers, while the solution flows to the rectification tower and a heater where at 3-4 bar pressure the remainder of the carbamate is decomposed. The gases condensed will be recycled, while the urea solution will be evaporated and the water free melt prilled in the prilling tower.

The urea plants have to be located at the same site as a corresponding sized or larger ammonia plant since the ammonia plant supplies not only ammonia but also the high purity carbon dioxyde.

Based on this new idea, complex ammonia-urea flowsheets were developed and tested in pilot plants, where the CO_2 removal is realised using an ammonia solution in water and the resulting liquor is introduced directly in the urea production. Since it does not seem advisable to propose for developing countries commercially not proven processes, this method was left out of consideration.

Based on a typical urea process, for this study, three plant sizes were considered, corresponding to the ammonia plant sizes selected in Chapter 3.2.1; 260 tpd, 440 tpd and 1700 tpd urea respectively. The main battery limit investment and consumption figures computed are summarized in Table 3.2.2-1, while the total and specific investment costs and factory gate prices in Fig. 3.2.2/2 and respectively Fig. 3.2.2/3. The detailed calculation can be found in Annex 3/1.

Taken into account the approximative nature of the data and methods used, it can be concluded, that the differences between the capacities are within the accuracy limits. Neither for specific investment costs, nor for factory gate prices, no economic disadvantage can be deduced for the mini-plants against the big units on the same sites.

The much more marked differences caused by the raw material used and its price reflect only the ammonia price movements.

For the nitrogenous fertilizers it seemed advisable to consider the economic conclusions together for all of them. Therefore farm gate prices and evaluation will be found at the end of chapter 3.2 (3.2.7).

Table 3.2.2-1

Battery limit costs and consumption figures for urea production /developed site/

Product: Urea				
Nominal capacity		260 t/d	440 t/d	1700 t/d
Battery limit cost	M$	10,8	16,4	48,0
Distribution of investment cost:				
- licence, know-how	%	23	23	23
- engineering	%	12	12	12
- equipment and machinery	%	52	52	52
- civil engineering and erection	%	33	33	33
Materials and Utilities Consumption/t urea:				
NH$_3$	kg	570	570	570
CO$_2$	kg	755	755	755
HP steam	kg	920	900	840
Power	kWh	150	140	130
Export steam LP	kg	-	-	50
Cooling water	m^3	70	70	60
Labour	men/shift	5	5	5

Fig. 3.2.2./2. Total (T.i.) and specific (Sp.i.) investment costs for various urea plants

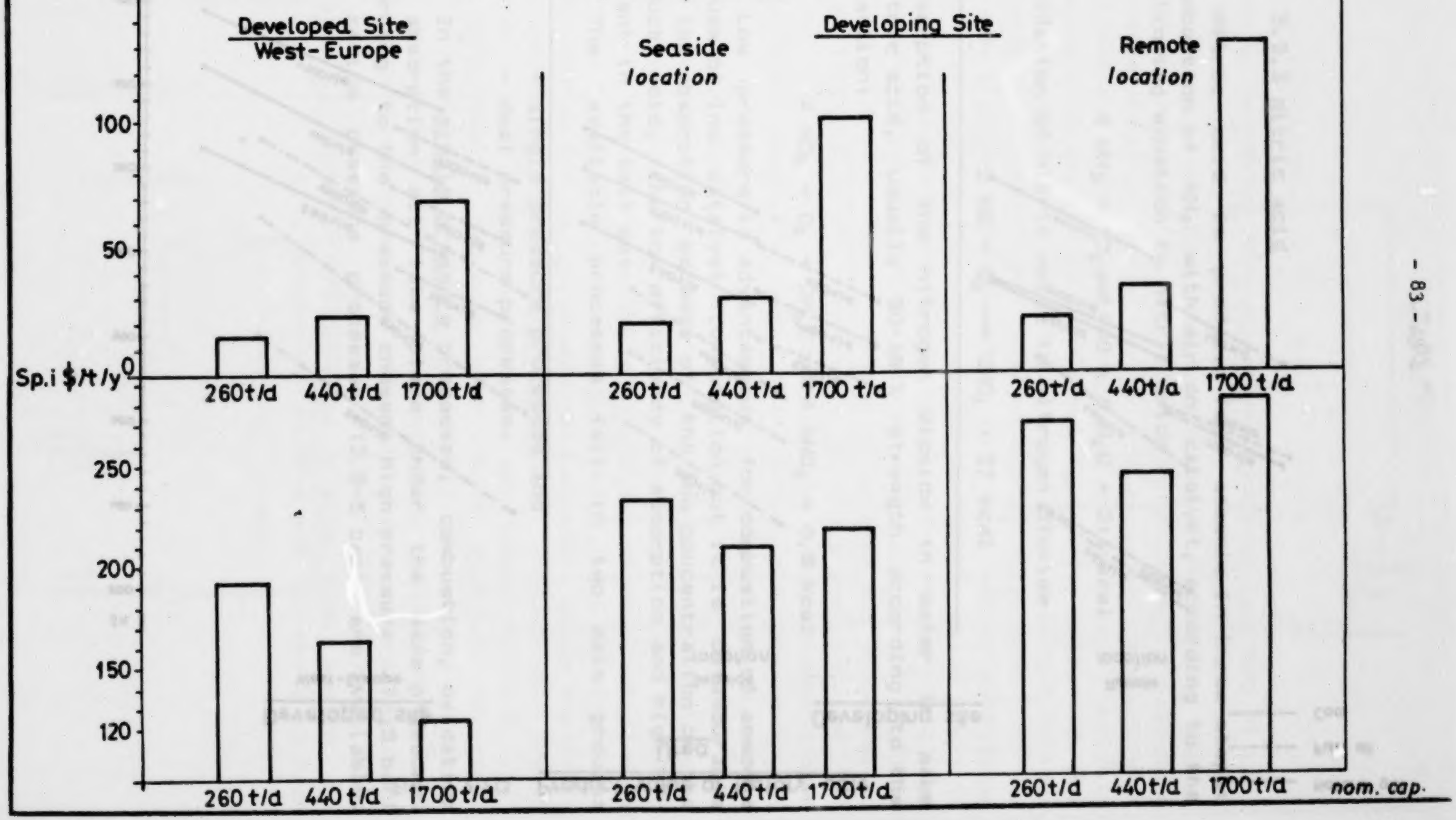
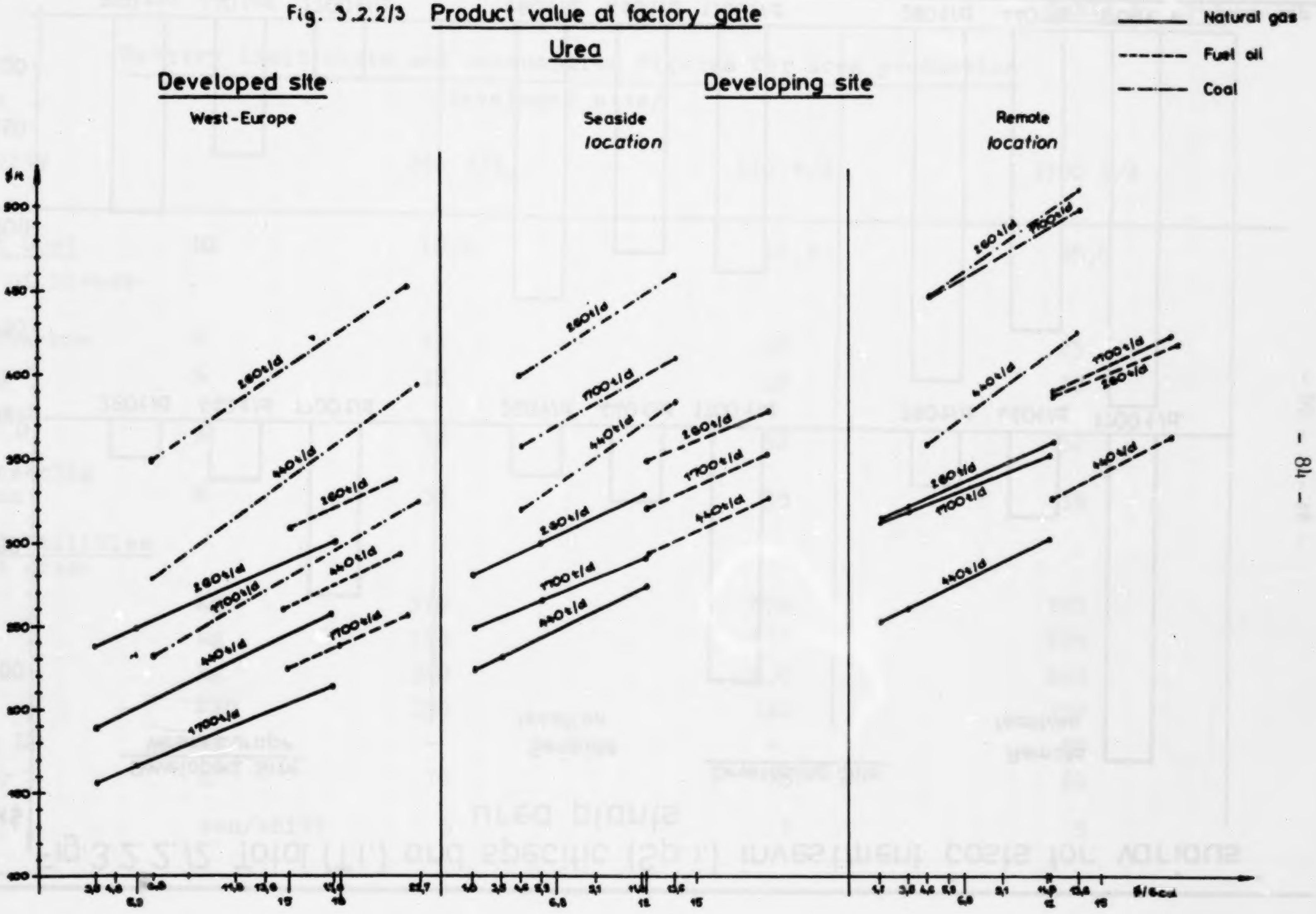


Fig. 3.2.2/3 Product value at factory gate

Urea



3.2.3 Nitric acid

Nitric acid is produced from ammonia in three steps:

- combustion of NH_3 with air on catalyst, according to the following equation to nitric oxide

$$4\ NH_3 + 5O_2 \rightleftharpoons 4NO + 6\ H_2O + 216\ \text{kcal}$$

- oxidation of nitric oxide to nitrogen dioxide

$$2\ NO + O_2 \longrightarrow 2NO_2 + 27\ \text{kcal}$$

- absorption of the nitrogen dioxide in water to make nitric acid, usually 50-68 % strength according to the reaction:

$$4\ NO_2 + O_2 + 2H_2O \rightleftharpoons 4\ HNO_3 + 0{,}9\ \text{kcal}$$

Low pressure is advantageous for combustion of ammonia because of low catalyst consumption but it is unfavourable for the absorption because of the low concentration of the product acid, the low efficiency of absorption and high NO content in the tail gas.

The available processes fall in two main groups:

- single pressure processes and
- dual pressure processes.

In the single pressure processes, combustion, oxidation and absorption all take place under the same pressure. According to the pressure chosen, high pressure (7-15 bar) and medium pressure processes (2.5-5 bar) are available.

In the dual pressure processes the oxidation pressure of NH_3 is held between 2.5 - 4.5 bar. At this pressure the burner dimensions are appreciably reduced compared with atmospheric pressure operation but the conversion of NH_3 is nevertheless high, of the order of 97 %. Consumption of platinum remains as low as at 100 mg/t HNO_3. The oxidation and absorption of nitrous gases are carried out at a pressure between 7-15 bar. It is possible to achieve yields of 99.5 % in the absorption stage within the economic limits on absorption column size. This yields corresponds to a residual nitrogen oxide content in the tail gas of 500 ppm by volume, but it is possible to design plant for tail gas concentrations as low as 200 ppm without catalitic tail gas treatment, by extending the absorption system.

We give here a typical flow sheet (Fig. 3.2.3/1) for a dual pressure nitric acid plant.

The specific consumption data are practically independent of the capacity of the plant.

There is no general rule for the choice of process conditions careful consideration of local conditions will decide. Small capacities as well as the very big ones give some preferences to the single pressure processes.

Table 3.2.3-1 summarizes the average values for three different sizes (always corresponding to the ammonia plant sizes) for battery limit costs and specific consumptions. Fig. 3.2.3/2 summarizes the total and specific investment costs for the same sizes. Here also can be seen that the advantage of the big plants exists only at developed sites: for sites lacking the necessary infrastructure even the specific capital costs are on the same level for both big and small plants.

Nitric acid being an intermediate product, evaluation will be given for the product fertilizer only.

Fig. 3.2.3./1. Dual pressure nitric acid plant.

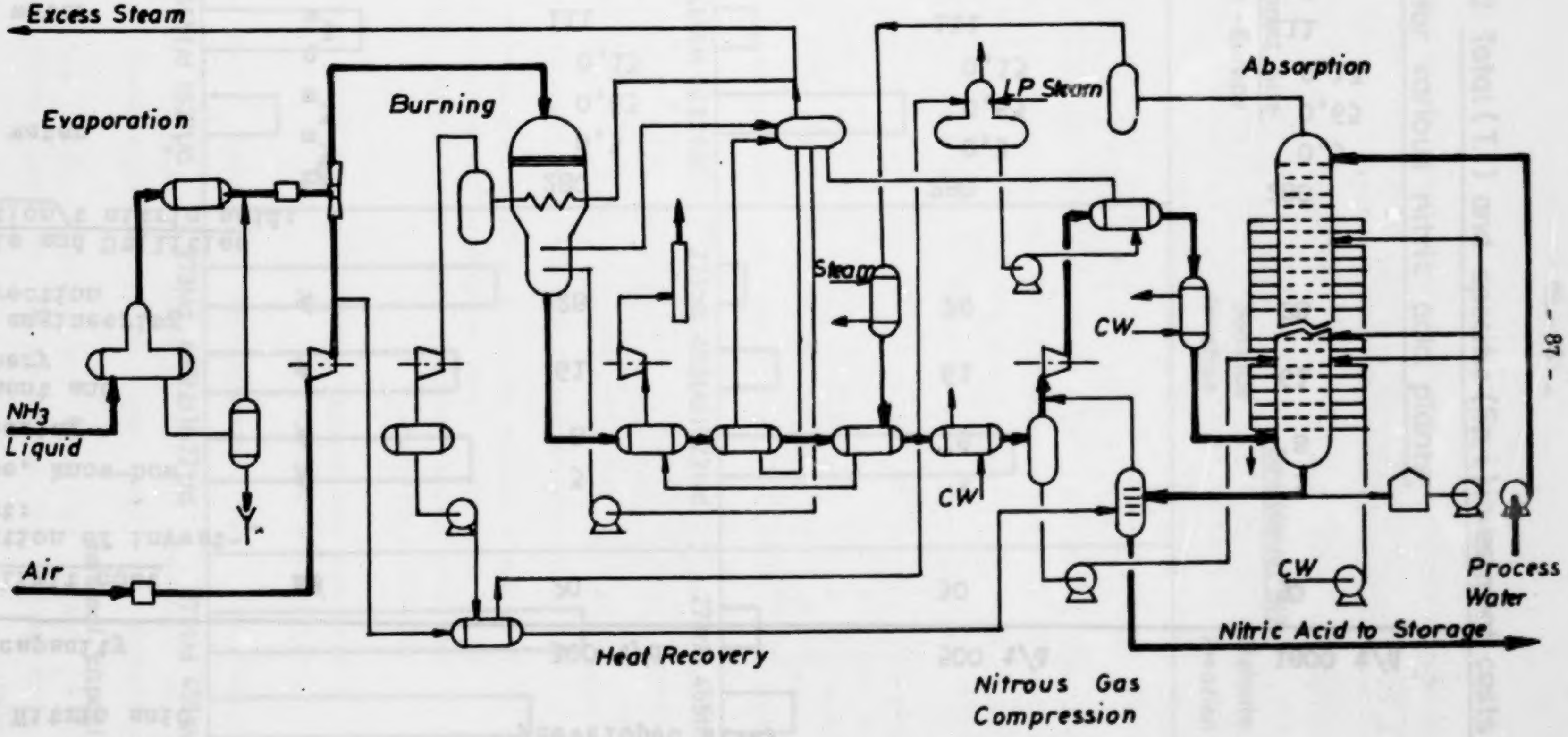

Excess Steam
Evaporation
Burning
NH3 Liquid
Air
Heat Recovery
Steam
LP Steam
CW
CW
Absorption
CW
Process Water
Nitric Acid to Storage
Nitrous Gas Compression

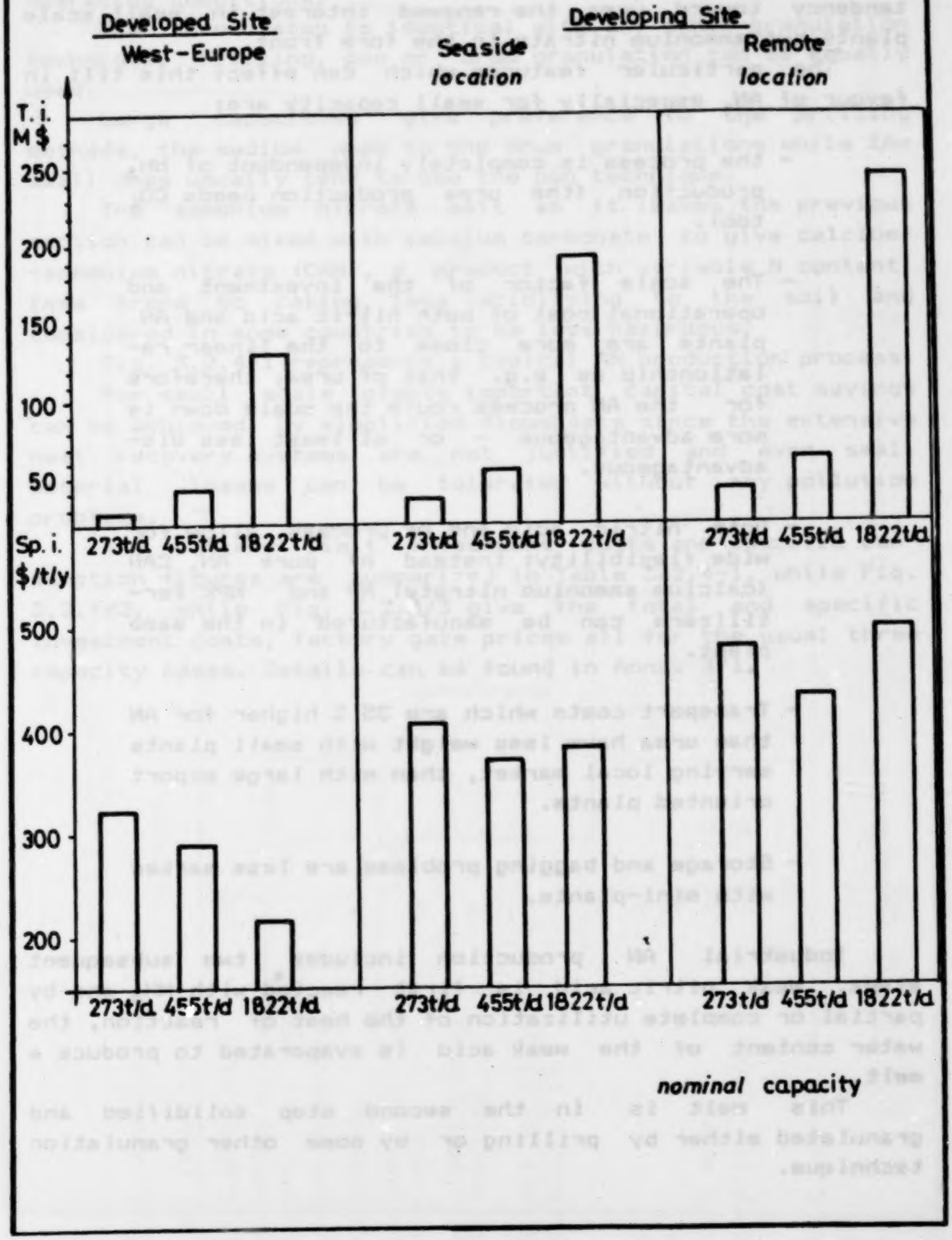
Table 3.2.3-1

Battery limit costs and consumption figures for nitric acid production
/developed site/

Product: Nitric acid

Nominal capacity		300 t/d	500 t/d	1800 t/d
Battery limit cost	M$	20	30	90
Distribution of investment cost:				
- licence, know-how	%	3	3	3
- engineering	%	8	8	8
- equipment and machinery	%	61	61	61
- civil engineering and erection	%	28	28	28
Materials and Utilities Consumption/t nitric acid:				
NH_3	kg	280	280	280
Process water	m^3	0,3	0,3	0,3
BFW	m^3	0,63	0,63	0,63
Pt	q	0,13	0,13	0,13
Cooling water	m^3	111	111	111
Power	kWh	13	13	13
Steam credit LP	t	0,4	0,4	0,4
Labour	men/shift	3	3	3

Fig. 3.2.3./2 Total (T.i) and specific (Sp.i.) investment costs for various nitric acid plants



3.2.4 Ammonium nitrate and CAN

Although the latest ten or twenty years showed a net tendency toward urea, the renewed interest in small scale plants put ammonium nitrate in the fore front.

The particular features which can effect this tilt in favour of AN, especially for small capacity are:

- the process is completely independent of NH_3 production (the urea production needs CO_2 too).

- The scale factor of the investment and operational cost of both nitric acid and AN plants are more close to the linear relationship as e.g. that of urea, therefore for the AN process route the scale down is more advantageous - or at least less disadvantageous.

- Both nitric acid and AN process allow for wide flexibility: instead of pure AN, CAN (calcium ammonium nitrate) NP and NPK fertilizers can be manufactured in the same plant.

- Transport costs which are 35 % higher for AN than urea have less weight with small plants serving local market, than with large export oriented plants.

- Storage and bagging problems are less marked with mini-plants.

Industrial AN production includes two subsequent steps. Weak nitric acid is first reacted with NH_3 and by partial or complete utilization of the heat of reaction, the water content of the weak acid is evaporated to produce a melt.

This melt is in the second step solidified and granulated either by prilling or by some other granulation technique.

In the first step the individual industrial processes differ in the choice of reaction conditions (temperature, pressure, heat utilization) and construction details. The aim is to achieve max. heat utilization and/or assure safe operating conditions.

The second step is identical with any other granulation technique. Prilling, pan or drum granulation can be equally used.

Large capacities give preference to the prilling methods, the medium ones to the drum granulations while the small ones usually tend to use the pan technique.

The ammonium nitrate melt as it leaves the previous section can be mixed with calcium carbonate to give calcium--ammonium nitrate (CAN), a product with variable N content, less prone to caking, less acidifying to the soil and considered in some countries to be less hazardous.

Fig. 3.2.4/1 represents a typical AN production process.

For small scale plants important capital cost savings can be achieved by simplified flowsheets since the extensive heat recovery systems are not justified and even small material losses can be tolerated without any pollution problems.

The battery limit investment costs and specific consumption figures are summarized in Table 3.2.4-1, while Fig. 3.2.4/2, while Fig. 3.2.4/3 give the total and specific investment costs, factory gate prices all for the usual three capacity cases. Details can be found in Annex 3/1.

Fig. 3.2.4/1. Production of AN with neutralization under pressure

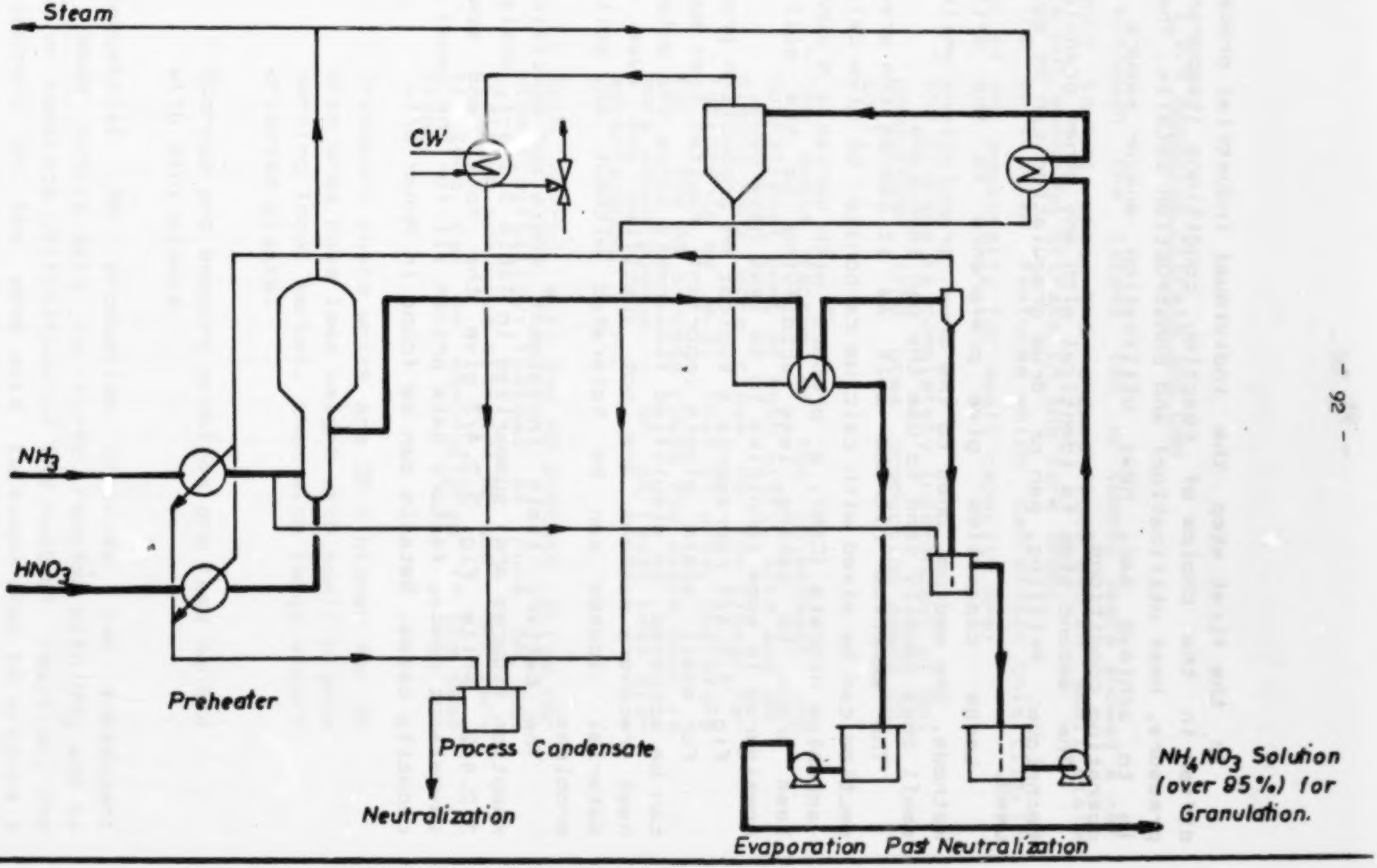

Steam
CW
NH_3
HNO_3
Preheater
Process Condensate
Neutralization
NH_4NO_3 Solution (over 85%) for Granulation.
Evaporation
Past Neutralization

Table 3.2.4-1

Battery limit costs and consumption figures for AN production

/developed site/

Product: Ammonium nitrate

Nominal capacity		360 t/d	600 t/d	2400 t/d
Battery limit cost	M$	7,5	11,2	33,6
Distribution of investment cost:				
- licence, know-how	%	3	3	3
- engineering	%	14	14	14.
- equipment and machinery	%	51	51	51
- civil engineering and erection	%	32	32	32
Materials and Utilities Consumption/t AN:				
NH_3	kg	205	205	205
HNO_3	kg	768	768	768
Lime	kg	32	32	32
Coating agent	kg	10	10	10
Anti-caking agent	kg	1	1	1
MgO	kg	3,3	3,3	3,3
Cooling water	m^3	38	38	38
Power	kWh	23	23	23
Steam	kg	240	240	240
Labour	men/shift	4	4	4

Fig. 3.2.4/2 Total (T.i) and specific (Sp.i.) investment costs for various ammonium nitrate plants

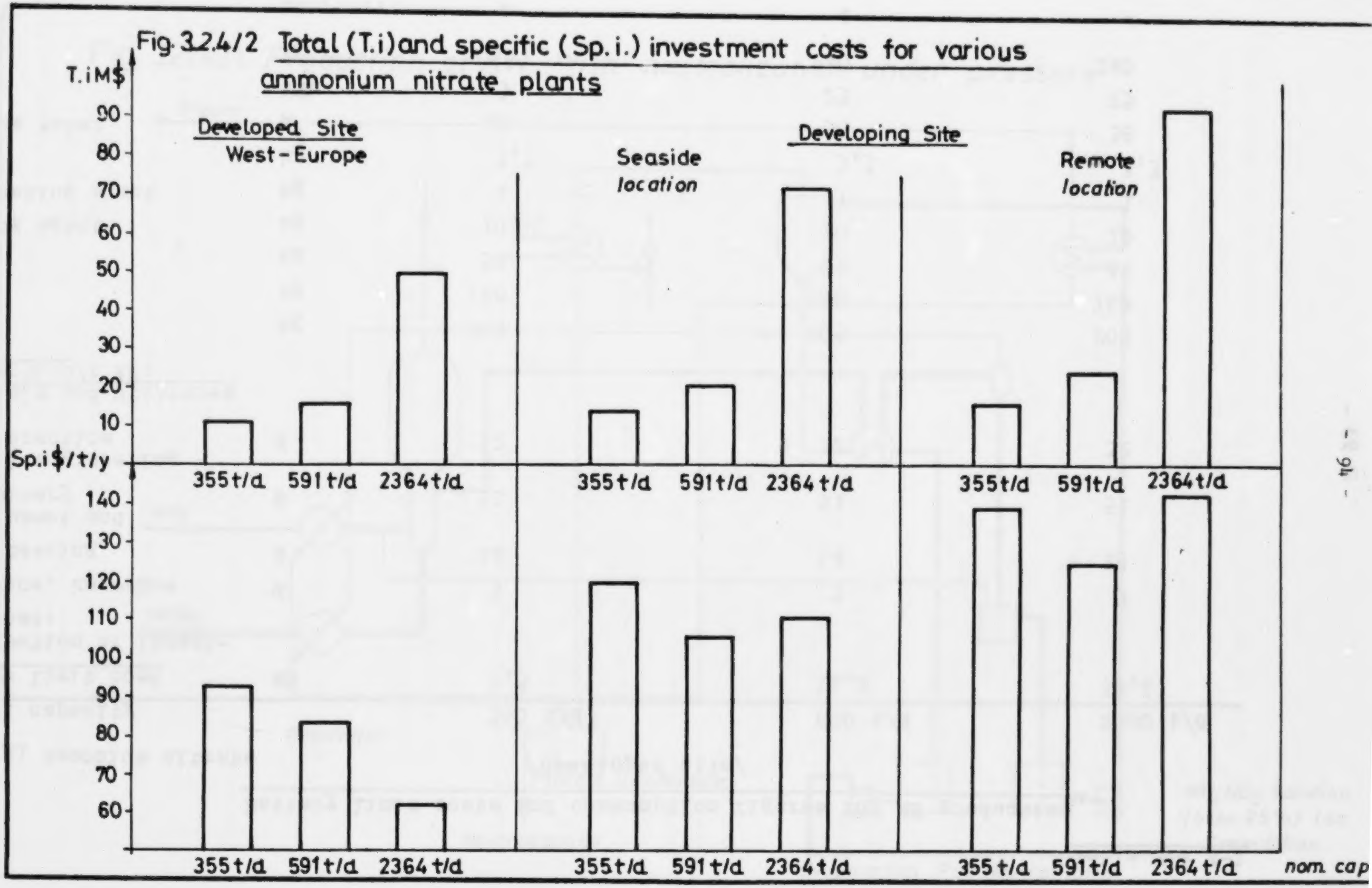
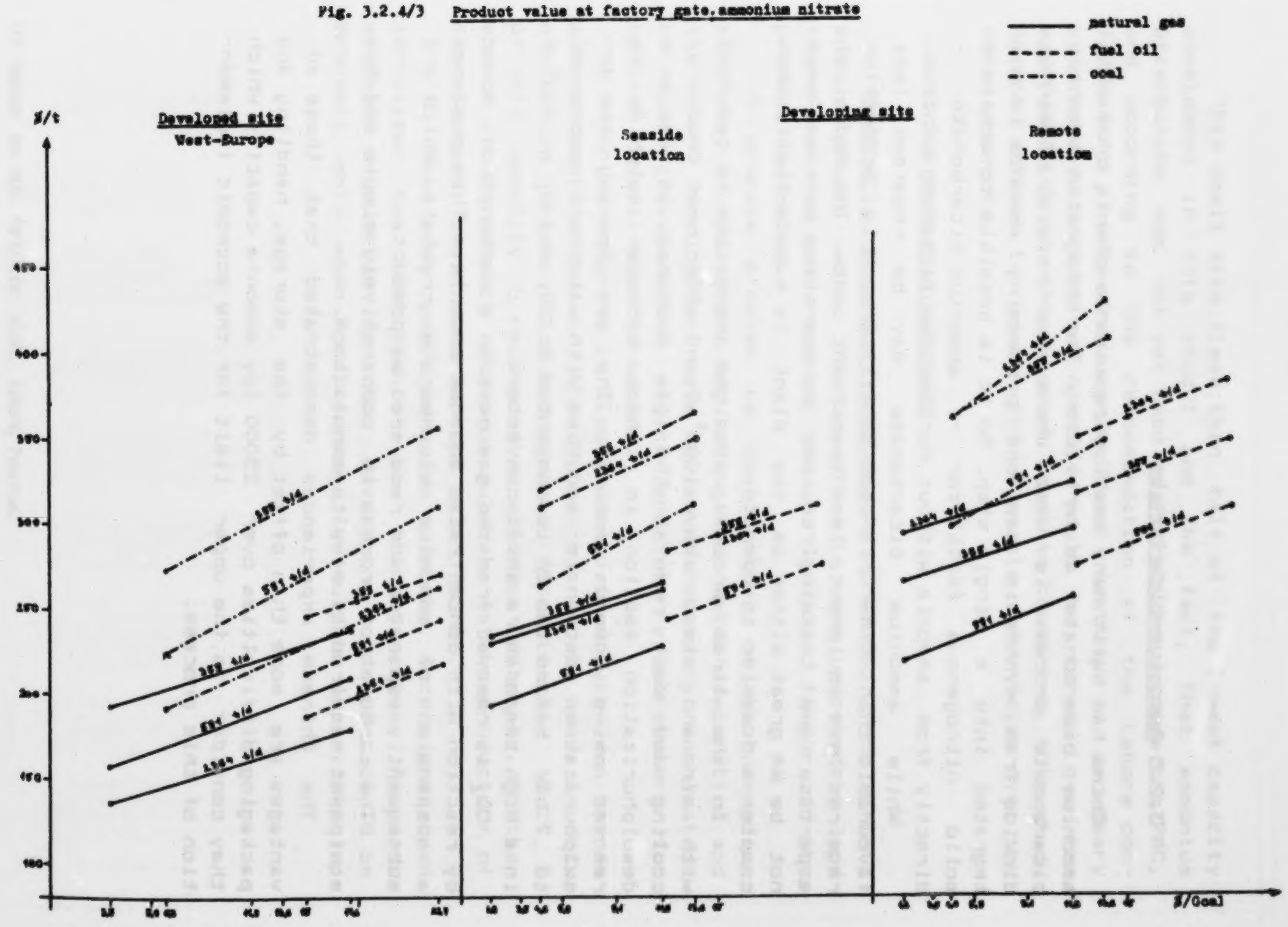


Fig. 3.2.4/3 Product value at factory gate, ammonium nitrate



3.2.5 Ammonium-bicarbonate

China has built many small-size ammonia plants producing ammonium bicarbonate as fertilizer. The integrated ammonium bicarbonate process is used where the removal of carbon dioxide from synthesis gas and processing ammonia is integrated into a single step. So it is possible to obtain a solid nitrogenous fertilizer - ammonium bicarbonate - directly from ammonia without further manufacturing process.

While ammonium bicarbonate may be regarded less favourable than other nitrogen fertilizers, this production requires less equipment, less investment costs. The technical expertise and training required by operating personal need not be as great either as the plant is substantially less complex and easier to operate.

In the first process step the anthracite is gasified with air and steam above 1000° C and after heat recovery, cooling and dust removal the gas produced is fed to a desulphurization section in which hydrogen sulphide is removed using aqueous ammonia. The gas leaving the desulphurization section is scrubbed with water and compressed to 7 bar before the CO is converted to CO_2 and H_2 at 400° C in a high temperature shift converter.

CO_2 is removed from the gas next in a carbonation tower by reaction with concentrated aqueous ammonia. This produces a suspension of ammonium bicarbonate crystals which are subsequently separated and recovered as product.

The carbonation process is comparatively simple and the equipment required is easy to manufacture.

The Chinese experiences demonstrated that these advantages are more than offset by the storage, handling and packaging difficulties over 25000 tpy ammonia capacity which they consider as the upper limit for the economic implemention of this process.

. This small size (less than half of the lowest capacity considered in this study) and the fact, that ammonium bicarbonate was not yet used as fertilizer outside the PRC, and according to the recommendation of the Lahore conference (1), extensive agricultural testing is necessary before any definitive opinion could be formed over the applicability of this product in other countries, this study do not attempt to asses its economic advantages over the other products.

3.2.6 Ammonium sulphate

Synthetic ammonium sulphate is produced from ammonia and sulphuric acid. The reaction is very exothermic and therefore the heat recovery is a decisive factor in the process economics.

A process problem is the control of the ammonium sulphate crystal size. Regulating the water evaporation and the slury circulation rate give the necessary combination of cooling/evaporation effect and slurry parameters for optimum crystal size formation.

Ammonium sulphate is also produced from coke oven gas as a by-product. Many of the bituminous coal used in coke production contain 1-2 % nitrogen and approximately 15-20 % of this quantity is recovered as ammonium sulphate. Another source of by-product ammonium sulphate is the production of caprolactame, basic material for nylon fibres.

In the past years ammonium sulphate, once a preferred fertilizer has lost much of its attractiveness. Ammonium sulphate production for the developing countries could be economic only when local sources for sulphur are available.

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(1) Seminar on mini fertilizer plant. Lahore, Pakistan. 15-20 November 1982, organized by UNIDO.

3.2.7 General assessment

Figures 3.2.7/1-2 sum up in a more complex way the data for the two most important fertilizer products: urea and ammonium nitrate, giving the compounded investment and production costs.

Figures 3.2.7/3 and 3.2.7/4 represent the farm-gate prices in the developing countries for each case investigated.

These prices include, above the value at factory gate (calculated with 15 per cent R.O.I.), also the distribution costs from the factory gate to the farmer, with the cost factors and values indicated in Appendix 3/1. Here, however, it was necessary to consider also the possible dimensions of the distribution area (which depend on the plant capacity) and also the level of fertilizer application, i.e., the amount of fertilizer used per 1 ha.

It has been supposed that a small plant has a distribution area of 100 km in diameter and the big plant, 300 km in diameter. The graph shows also the farm gate prices for imported fertilizer in a region of 100 km, and 300 km dia.respectively; these prices have been deducted from the costs of a European natural gas based big plant (natural gas price 50 and 100 US Dollar/10^3 m^3) respectively, increased by the costs for sea freight, plus in the case of remote location, road transport costs finally distribution costs characteristic for a supply region of identical dimensions.

Thus, it may be read from the graph whether the fertilizer costs at farm-gate are similar, better or less advantageous than those of imported fertilizers.

Fig. 3.2.7/1 Total (T.i) and specific (Sp.i) investment costs for various ammonia-urea complexes

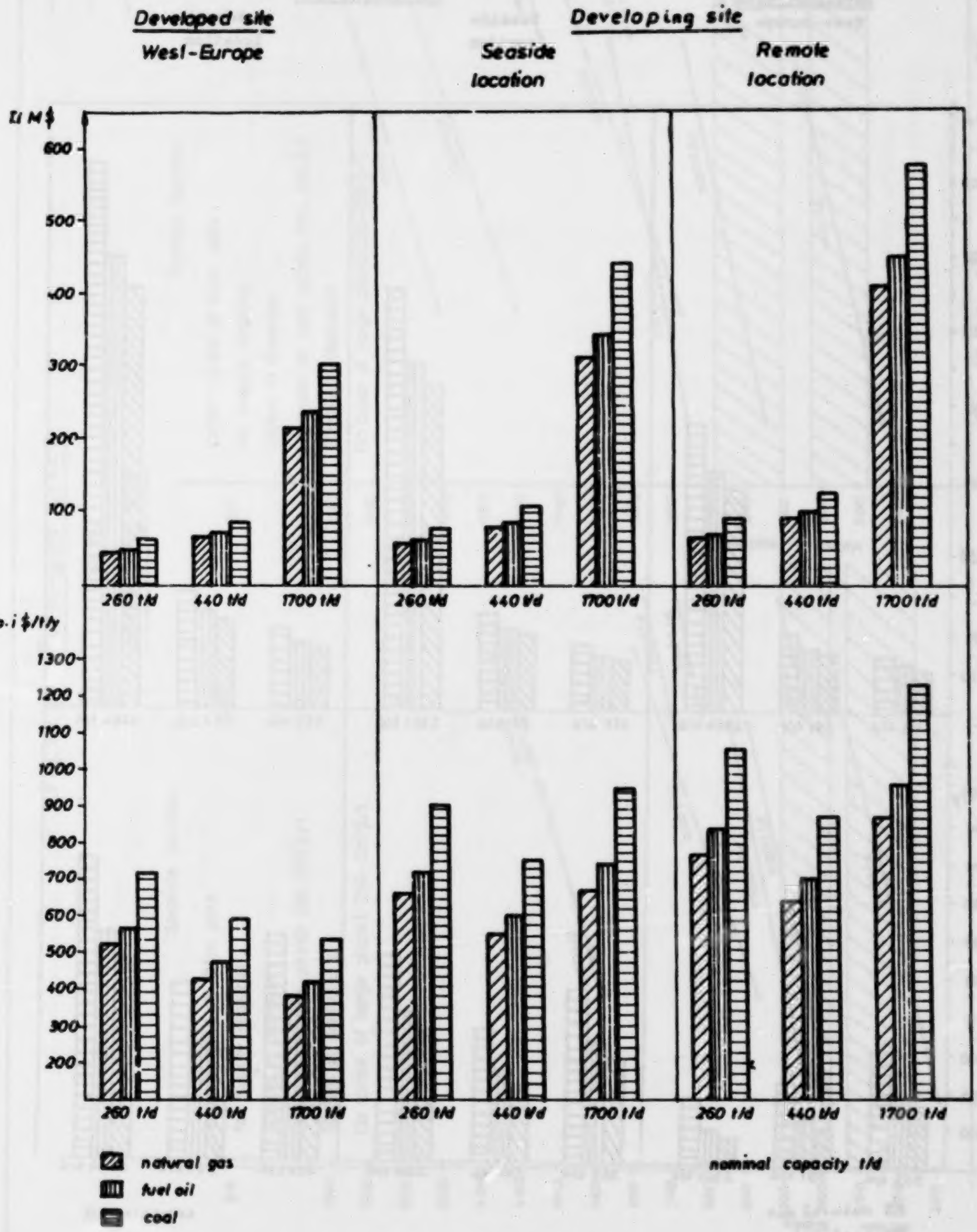
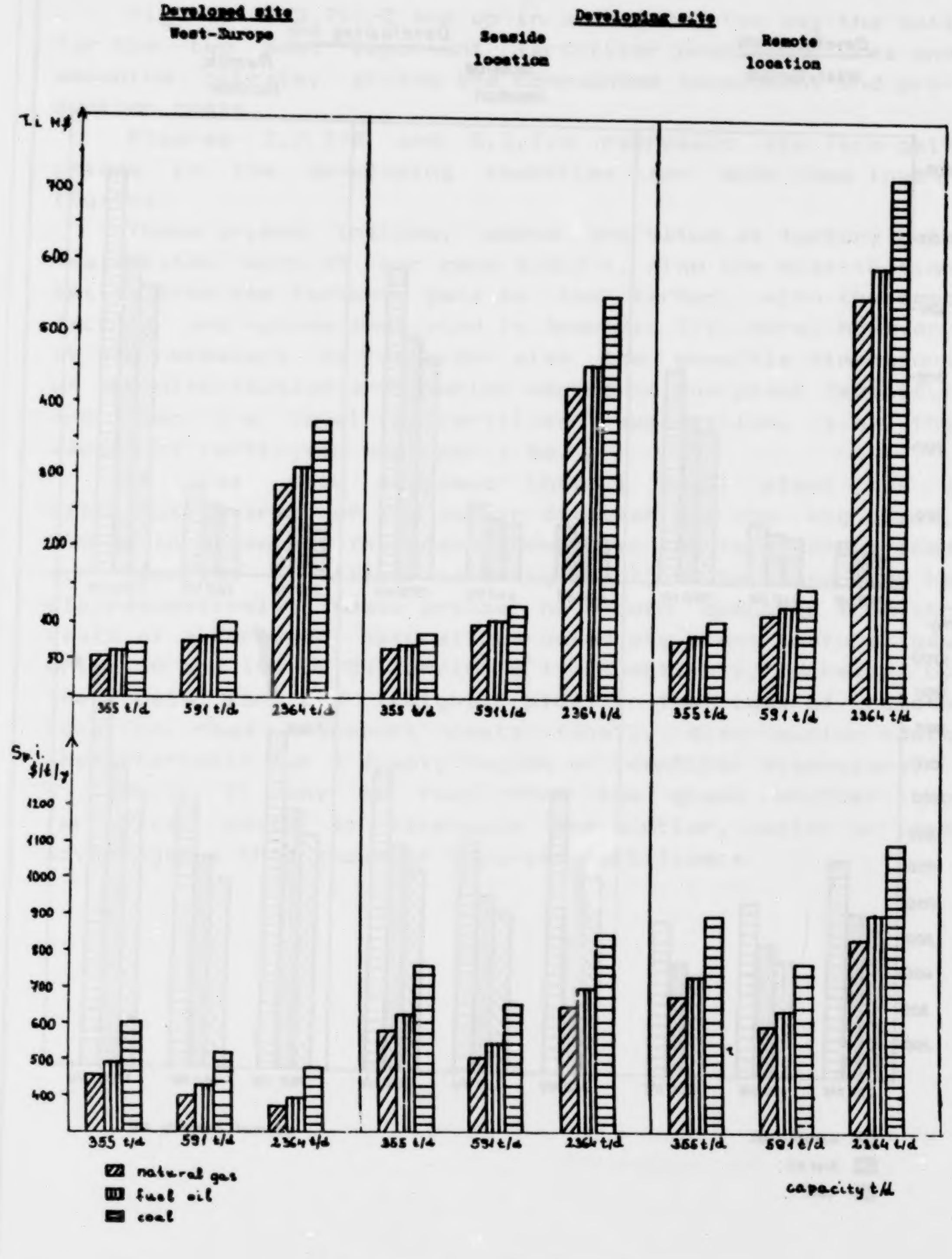


Fig. 3.2.7/2 Total /T.i./ and specific /Sp.i./ investment costs for various ammonia -nitric acid- ammonium nitrate complexes



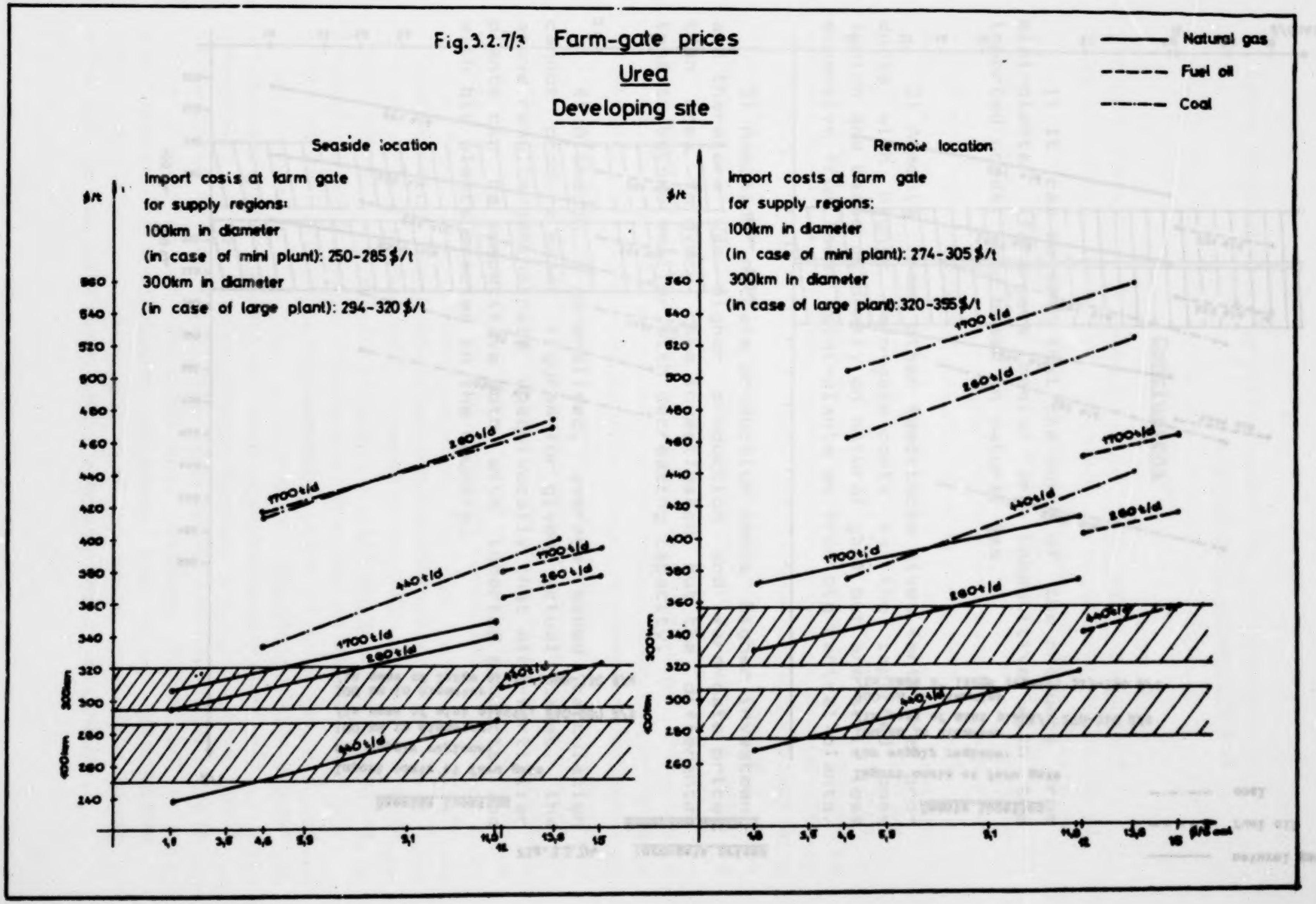


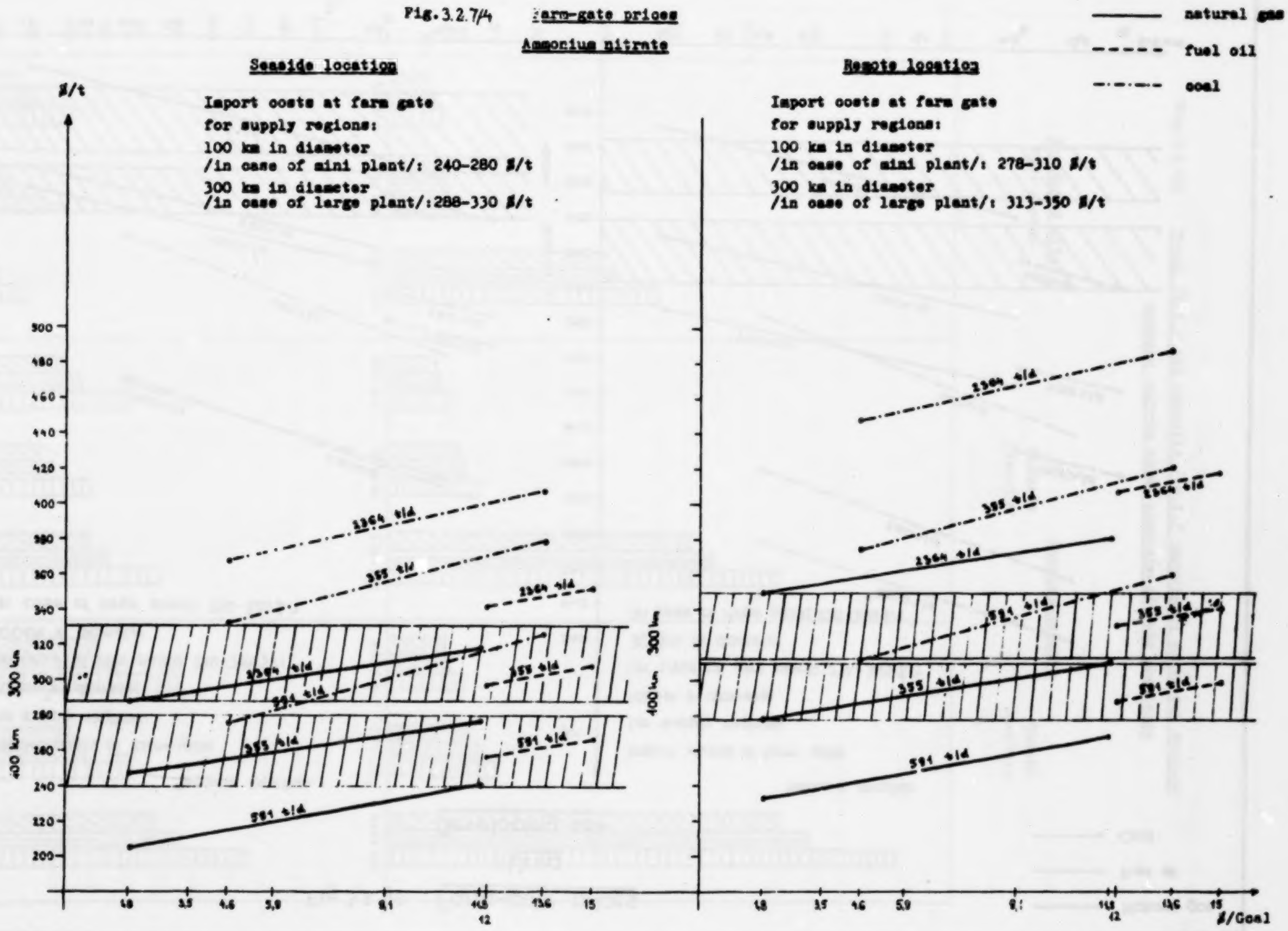
Fig.3.2.7/3 Farm-gate prices

Urea

Developing site

Fig.3.2.7/4 Farm-gate prices

Ammonium nitrate



Seaside location

Import costs at farm gate
for supply regions:
100 km in diameter
/in case of mini plant/: 240-280 $/t
300 km in diameter
/in case of large plant/: 288-330 $/t

Remote location

Import costs at farm gate
for supply regions:
100 km in diameter
/in case of mini plant/: 278-310 $/t
300 km in diameter
/in case of large plant/: 313-350 $/t

Conclusions

1) It can be seen that the costs of the products from mini-plants (farm-gate basis) are competitive with the imported goods, when based on natural gas.

2) Ammonia from other feedstocks gives fertilizer products with higher farm-gate costs as the imported ones (which are based evidently on natural gas) but are still less expensive from local mini-plants as from big central plants.

3) Ammonium nitrate production needs higher investment and therefore has higher production and farm-gate prices than urea in every case investigated, but the differences tend to become smaller with decreasing capacity.

4) Although a generalised, average based calculation cannot produce exact figures for given actual cases, the above results demonstrate unequivocally that mini-fertilizer plants can be competitive both with imported products and with big plants erected in the country.

3.3 Phosphate Fertilizers

Introduction

Phosphate rock can be processed by different routes: by physical methods or by chemical treatment. Sulphuric acid or nitric acid are used for this purpose.

Physical methods (e.g. thermo-phosphates), will be successful only with a small category of phosphate rocks. Most ores require chemical treatment.

The nitric acid route is not convenient for the mini-plant concept: the necessary investment is higher, the sophisticated process poses the highest challenge on the operating personal and the product is unfavourably limited in the N:P ratio to minimum 1:1; higher phosphorus content is not possible. Water solubility - although a much discussed propriety - is also limited.

Sulphuric acid based processes are simple, easy to install and run. Therefore, for the purpose of mini-plant study, only sulphuric acid route will be considered.

The two important basic-products are sulphuric and phosphoric acid. The sulphuric acid is needed in all phosphate processing plants either for phosphate processing plants or for phosphoric acid production or a basic raw material for normal superphosphate production. On the other hand, phosphoric acid is the basic raw material for all the other processes.

Three different process lines are discussed in the study.

The first consists of sulphuric acid and normal (single) superphosphate (SSP) processes. The basic unit is the sulphuric acid plant with a capacity of 200 tpd (66000 tpy). The capacity of normal superphosphate (SSP) plant is defined by its sulphuric acid consumption: 500 tpd (160000 tpy), single superphosphate.

The second process line involves sulphuric acid, phosphoric acid and triple superphosphate (TSP) processes; and in this case the phosphoric acid plant is the basic unit.

The third process line includes the sulphuric acid, phosphoric acid and ammonium phosphates processes; the phosphoric acid plant is the basic unit in this case, too.

According to the process lines described above, the main types of phosphate fertilizers are the following:

Type	Grade (%)
Single superphosphate (SSP)	0-18-0
Triple superphosphate (TSP)	0-46-0
Monoammonium phosphate (MAP)	12-52-0
Diammonium phosphate (DAP)	18-46-0

The capacity considered for the phosphoric acid plant is 200 tpd (66000 tpy), defining the capacity of the other plants; sulphuric acid (600 tpd), TSP (500 tpd), MAP (375 tpd), DAP (425 tpd). Consequently, the plants with the above mentioned capacities will be considered in this study as mini-plants.

In contrast with the nitrogen industry in the whole phosphate industry mini-, small, medium and big plants operate all over the world and new projects are implemented continuously with every possible capacity. The process flow-sheet and equipment used are similar; only a few simplifications can be observed with the smaller sizes. It is only the phosphoric acid plant where with the modern up-to-date technics require a minimum size (although this is also flexible) for competitiveness. In SSP and TSP production the process equipment represents only a fraction of the battery limit capital costs: material handling and storage are the main factor. Therefore the scale factor is very close to the linear.

The capacities considered are thus typical examples only and any capacity justified by local conditions can be adopted. The economics influencing the decision will be dealt with at the end of the relevant chapter.

3.3.1 Sulphuric Acid

This is the basic product for any phosphate fertilizer production. While rock and even the raw material for this acid production can be imported, acid itself must be locally produced.

As it was mentioned earlier, a mini-plant with a capacity of 200 tpd (66000 tpy) is considered for the normal superphosphate line and another with a capacity of 600 tpd (200000 tpy) to supply the phosphoric acid plant.

Raw materials may be:

- Elementar Sulphur or
- Pyrites or
- Non-ferrous metal ore processing.

The last case can be excluded from the mini-plant concept, since the capacity of the sulphuric acid plant will be set by the quantity of the by-product gases of the ore processing unit.

3.3.1.1 Elementar Sulphur Based Sulphuric Acid Process

The molten sulphur and dried air are introduced into the sulphur furnace (Fig. 3.3.1/1), where the sulphur burns with the oxygen to form gaseous sulphur dioxide, with the liberation of considerable heat. The hot gases leaving the furnace pass directly into a waste heat boiler, which generates high pressure steam and thereby cools the gases.

The cooled gases pass in the converter, where sulphur dioxide in the presence of air is converted to sulphur trioxide. The gases leaving the converter are cooled and introduced into the absorption system, where the sulphur trioxide is absorbed in sulphuric acid. Water is added to the circulating acid to control the concentration of the acid.

Product acid is withdrawn from the circulating system and will be available for further use.

Since similar techniques are used for the production of acid from various sulphide ores, and for mini-plants, practically only pyrite can be taken into account. This study will discuss a process typical for use of pyrite (Fig. 3.3.1/2).

LIST OF EQUIPMENT FOR H_2SO_4 PLANT
SULPHUR BURNING TYPE.

1. Main Blower
2. Drying Tower
3. Sulphur Pit
4. Sulphur Filter
5. Sulphur Furnace
6. Waste Heat Boiler
7. Heat Exchanger
8. Hot Gas filter
9. Converter
10. Superheater
11. Absorption Tower
12. Degassifier
13. Boiler Feedwater Pump
14. Absorption Tower Acid Cooler
15. Absorption Tower Pump Tank
16. Product Acid Cooler
17. Acid Dilution Mixer
18. Diluted Acid Cooler
19. Acid Drain Pump

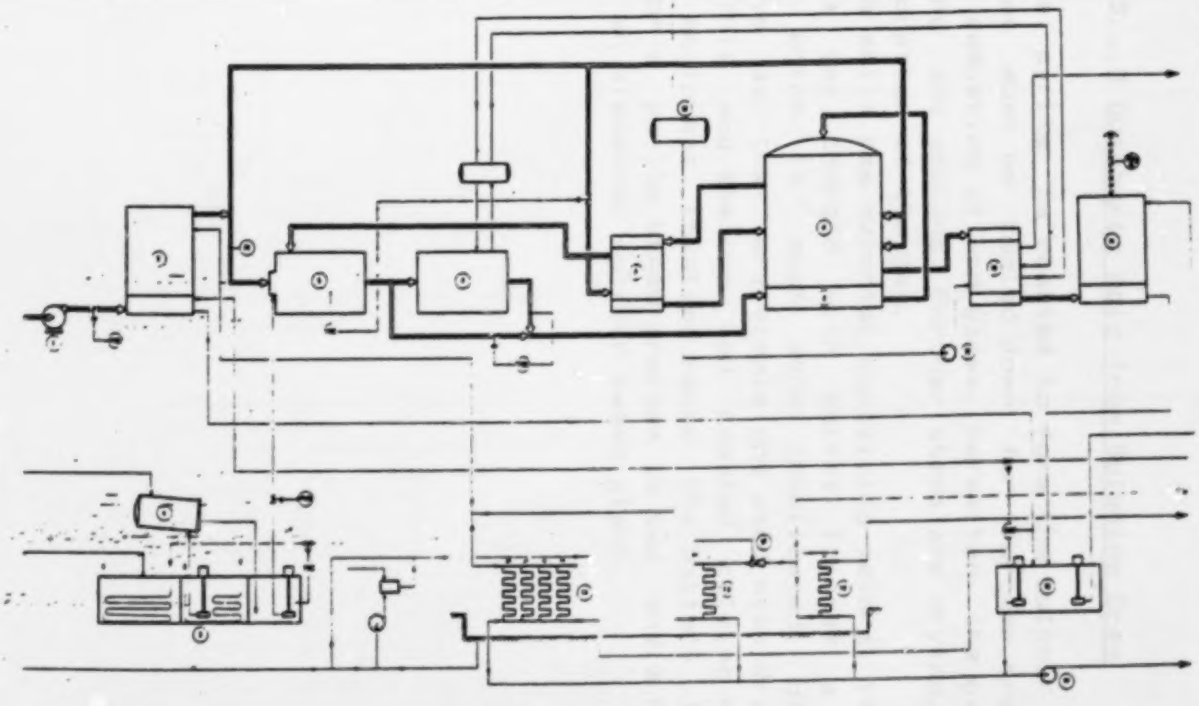


Fig 3.3.1/1
SULPHURIC ACID PROCESS
(SULPHUR BASED)

3.3.1.2 Sulphuric Acid from Sulphide Ores

The pyrite is roasted to form the sulphur dioxide, and the gases must be cooled down for further treatment. Then follows dedusting of the gases, hereafter the gases pass wet scrubbing and cooling. Further steps are drying, conversion and absorption of the gas.

The solid raw material containing several impurities and giving a gas charged with solids imposes a purification system which is much more complicated, difficult and expensive as the very simple one used with brimstone feedstock. This and the ore and roasted calcine handling and storage equipment involved raise the battery limit capital costs for a pyrite based process to two and a half times of that of an elementar sulphur based plant.

LIST OF EQUIPMENT FOR H_2SO_4 PLANT.

1. Pyrite Weighing Belt
2. Pyrite Conveyor with Tripper
3. Pyrite Storage Bin
4. Pyrite Extraction Belt
5. Pyrite Screw Feeder
6. DorrCo FluoSolids Reactor
7. Waste Heat Boiler
8. Gas Cyclone Unit
9. Reactor Main Blower
10. Reactor Start-Up Blower
11. Reactor Start-Up Burner
12. Reactor Overflow Valve
13. Calcine Discharge Valve
14. Calcine Chain Conveyor
15. Degassifier
16. Boiler Feedwater Pump
17. Gascooler-Scrubber
18. Lower Recycle System
19. Upper Recycle System
20. Weak Acid Cooler
21. Weak Acid Stripping System
22. Dorr-Oliver Thickener
23. Dorr-Oliver Rotating Vacuum Drum Filter
24. Dorr-Oliver Filtrate Receiver
25. Vacuum Pump
26. Filtrate Pump
27. Electrostatic Mist Precipitator
28. Acid Stripping Tower
29. Drying Tower
30. Gas Blower
31. Absorption Tower
32. Heat Exchanger
33. Converter
34. Economiser
35. Starting-Up Furnace
36. Preheater
37. Drying Tower Acid Cooler
38. Drying Tower Pump Tank
39. Absorption Tower Acid Cooler
40. Absorption Tower Pump Tank
41. Product Acid Cooler
42. Acid Dilution Mixer
43. Diluted Acid Cooler
44. Acid Drain Pump

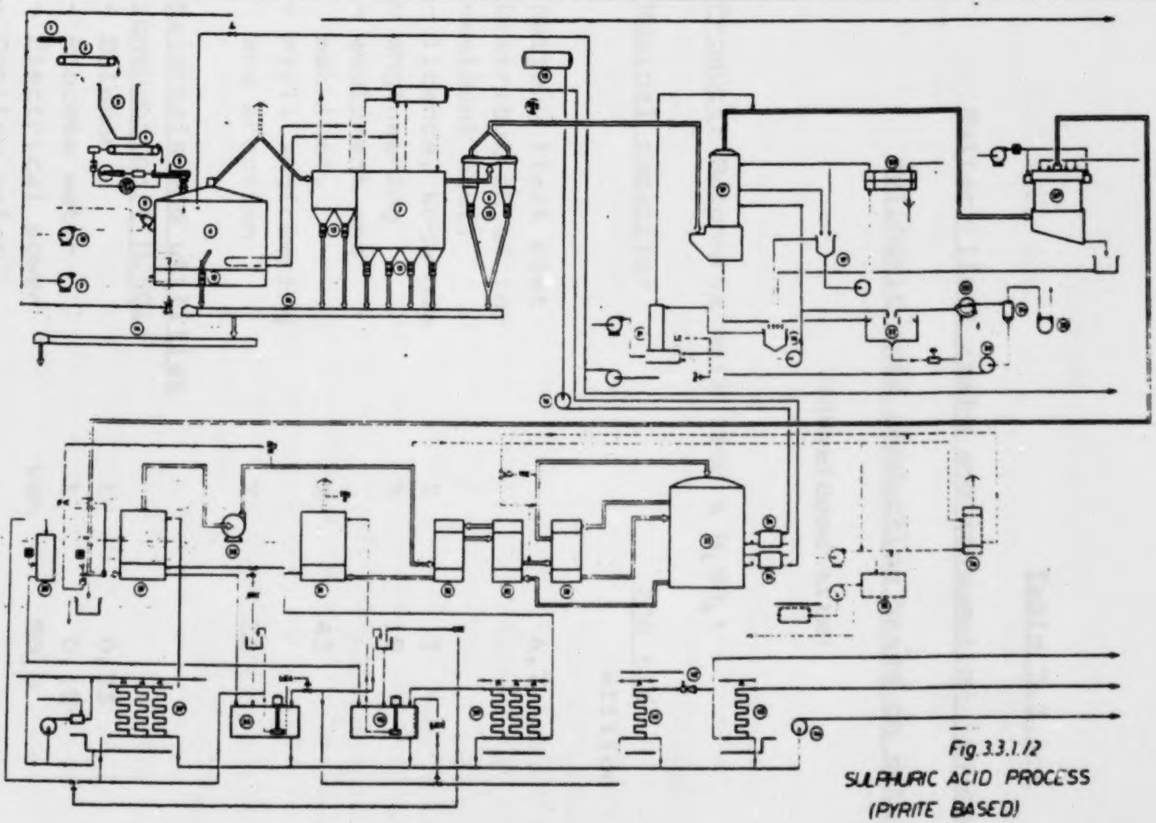


Fig. 3.3.1/2
SULPHURIC ACID PROCESS
(PYRITE BASED)

Table 3.3.1-1

Battery limit costs and consumption figures for sulphuric acid production based on sulphur

(developed site)

Product: Sulphuric Acid (100 % H_2SO_4)

Nominal capacity:		200 t/d	600 t/d
		million	dollar
Battery limit cost		6,7	15,5
Distribution of investment cost:			
- licence, know-how	%	3	3
- engineering	%	18	18
- equipment and machinery	%	43	43
- civil engineering and erection	%	36	36
Materials and utilities consumption/t H_2SO_4:			
- Sulphur	t	0,33	0,33
- Process water	t	0,15	0,15
- Electrical power	kWh	50,0	50,0
- Cooling water circulation	t	37,0	37,0
- Gross steam production	t	1,2	1,2
Labour	men/shift	4	5

Table 3.3.1-2

Battery limit costs and consumption figures for sulphuric acid production based on pyrite

(developed site)

Product: Sulphuric acid (100 %, H_2SO_4)

Nominal capacity		200 t/d	600 t/d
		million	dollar
Battery limit cost		16,8	38,7
Distribution of investment cost:			
- licence, know-how	%	3	3
- engineering	%	16	16
- equipment and machinery	%	46	46
- civil engineering and erection	%	35	35
Materials and utilities consumption/t H_2SO_4:			
- Pyrite (44 % S)	t	0,81	0,81
- Process water	t	0,25	0,25
- Electrical power	kWh	98,00	98,00
- Cooling water	t	72,00	72,00
- Gross steam production	t	1,20	1,20
Labour	men/shift	8	10

Economic evaluation

Table 3.3.1-1 and 3.3.1-2 summarizes the specific consumption and battery limit capital costs for the wo capacities envisaged respectively the two feedstocks. Fig 3.3.1/3 represents the total and the specific investment costs. Detailed data and calculation can be found as usual in Appendix 3/1.

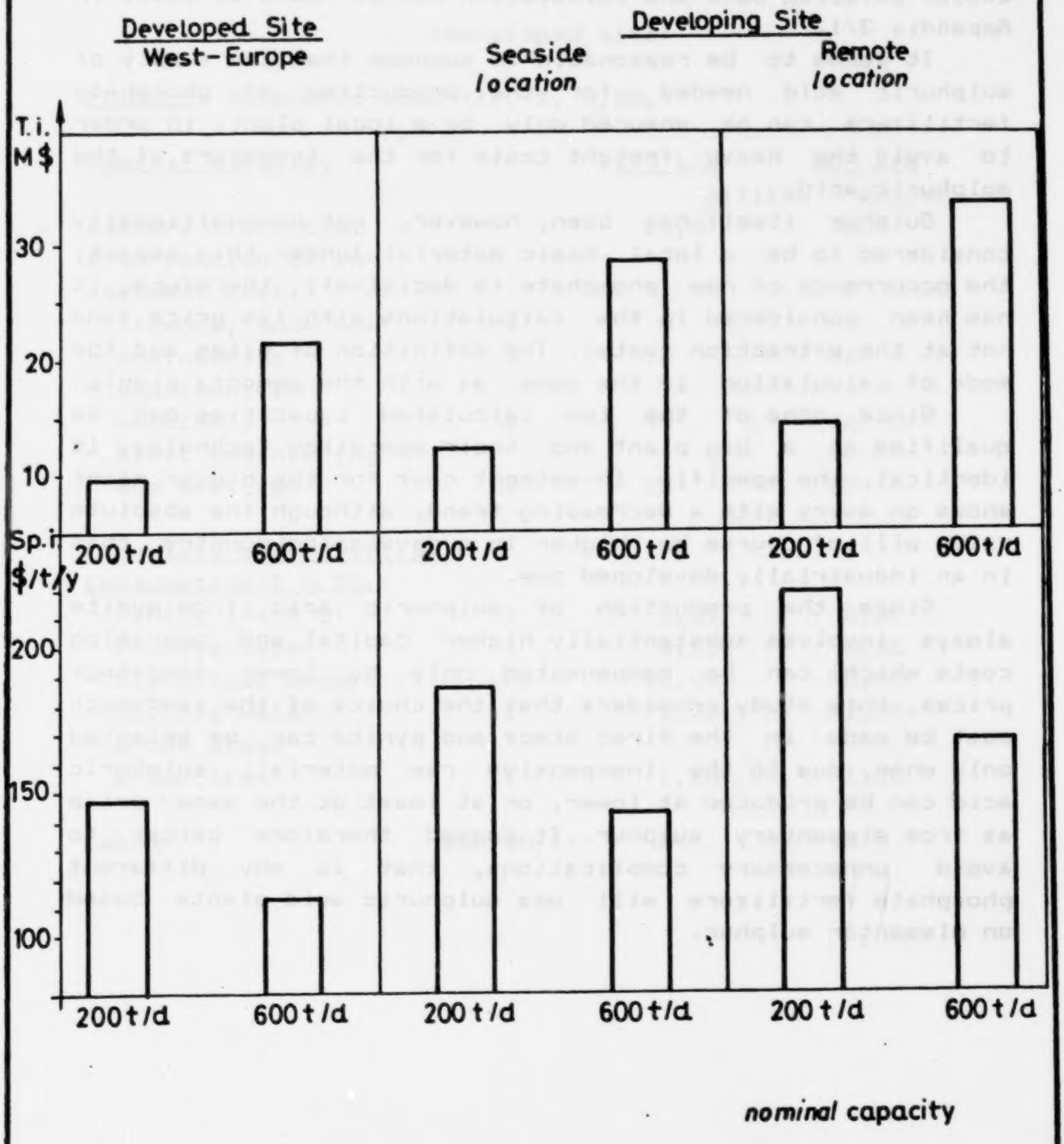
It seems to be reasonable to suppose that the supply of sulphuric acid needed for the production of phosphate fertilizers can be ensured only by a local plant, in order to avoid the heavy freight costs for the transport of the sulphuric acid.

Sulphur itself has been, however, not unconditionally considered to be a local basic material (under this aspect, the occurrence of raw phosphate is decisive); therefore, it has been considered in the calculations with its price (and not at the extraction costs). The definition of sites and the mode of calculation is the same as with the ammonia plants.

Since none of the two calculated capacities can be qualified as a big plant and their operating technology is identical, the specific investment cost for the bigger plant shows on every site a decreasing trend, although the absolute value will of course be higher in a developing country than in an industrially developed one.

Since the production of sulphuric acid from pyrite always involves substantially higher capital and operating costs which can be compensated only by lower feedstock prices, this study considers that the choice of the feedstock must be made in the first steps and pyrite can be selected only when, due to the inexpensive raw material, sulphuric acid can be produced at lower, or at least at the same price as from elementary sulphur. It seemed therefore better to avoid unnecessary complications, that is why different phosphate fertilizers will use sulphuric acid plants based on elementar sulphur.

Fig. 3.3.1/3 Total (T.i) and specific (Sp.i.) investment costs for various sulphuric acid plants



3.3.2 Normal (Single) Superphosphate (SSP) Process

Normal superphosphate (SSP) was, for many years, by far the most popular phosphate fertilizer. Since the mid--fifties, however, this popularity has been in a sharp decline and only in the past few years this rate began to slow-down.

Normal superphosphate can be manufactured in small inexpensive plants with low production costs. The process is simple and easy to operate requiring less sulphur per ton of P_2O_5 than the production of phosphoric acid. The combination of low investment and simplicity together with recognition of the deficiency of sulphur in many soils assures that SSP production will remain competitive, especially for mini-plants, where the small distribution area reduces considerably the difference in transport costs.

The two raw materials used in the production of SSP are 65 to 75 % sulphuric acid and ground phosphate rock. The basic chemical reaction is shown by the following equation:

$$Ca_3(PO_4)_2 + 2\,H_2SO_4 + 5\,H_2O =$$
$$= 2\,CaSO_4 \cdot 2H_2O + Ca\,(H_2PO_4)_2 \cdot H_2O$$

The interval of fluidity before the two reactants solidify is very brief and the mixture is quickly transferred to an enclosed space referred to as a den. This den may be either an essentially stationary structure or a continuous slow moving conveyor. In the den the material becomes relatively quickly plastic. During this phase there is a copious evolution of obnoxious gas as the crystallization process progress.

Retention time in the den can range from 1 to 4 hours depending on the overall process conditions. At the end of this time, the material becomes a porous mass resembling a honeycomb and is removed from the den to storage. A storage period of 3 to 8 weeks is required for curing before the SSP is an acceptable product for shipment. The curing time serves to allow completion of the chemical reaction between the rock and acid with the subsequent decrease in free acid and citrate insoluble P_2O_5-content.

Fig. 3.3.2/1 gives a typical flowsheet for an SSP plant. Table 3.3.2-1 contains the battery limit costs and specific consumptions for the capacity case chosen (500 tpd SSP). Economic evaluation will be found in paragraph 3.3.4 together with the other phosphate fertilizer products.

Table 3.3.2-1

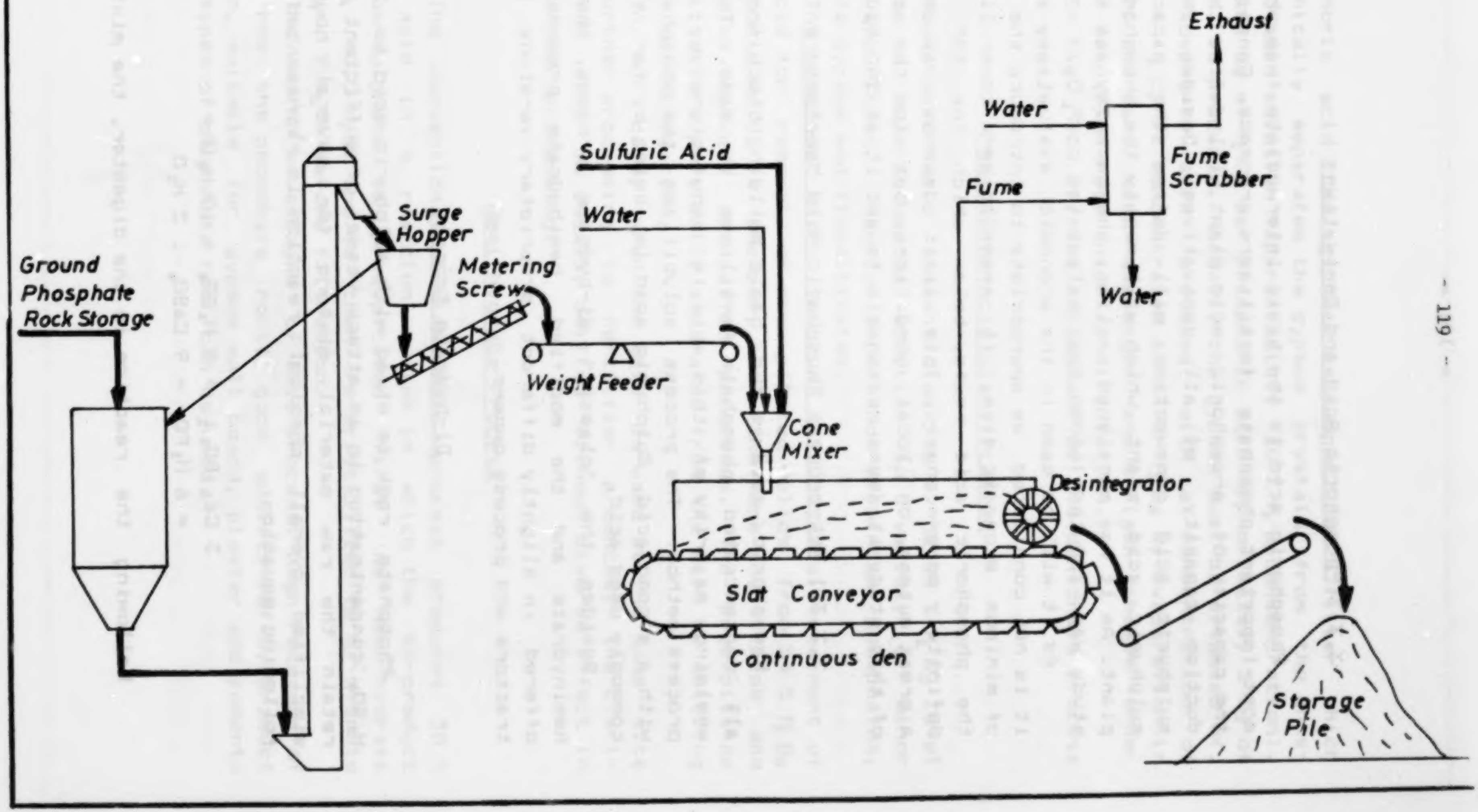
Battery limit cost and consumption figures

for run of pile SSP production

(developed site)

SSP (18 % P_2O_5)		
Nominal capacity		500 t/d
		million dollar
Battery limit cost		3,0
Distribution of investment cost:		
- licence, know-how	%	3
- engineering	%	15
- equipment and machinery	%	45
- civil engineering and erection	%	37
Materials and utilities consumption/t SSP		
- Phosphate Rock (dry 32,5 % P_2O_5)	t	0,58
- Sulphuric Acid (100 % H_2SO_4)	t	0,36
- Electrical power	kWh	6,0
- Process Water	m^3	2,0
Labour	men/shift	5

Fig. 3.3.2. /1 Continuous Manufacture of Single Superphosphate


Ground
Phosphate
Rock Storage
Surge
Hopper
Metering
Screw
Weight Feeder
Sulfuric Acid
Water
Cone
Mixer
Fume
Water
Fume
Scrubber
Exhaust
Water
Desintegrator
Slat Conveyor
Continuous den
Storage
Pile

3.3.3 Phosphoric Acid and Derivatives

Phosphoric acid is the basic intermediate from which the most important phosphate fertilizers are made. Consequently, the capacity of phosphoric acid plant will define the production capacity of all derivatives. Besides that its sulphuric acid consumption will define the capacity of sulphuric acid plant which will supply the phosphoric acid plant. As it was mentioned earlier, the capacity set for this study was 200 tpd (66000 tpy) calculated in P_2O_5.

As it will be seen in the economic evaluation, although it is not considered as appropriate to introduce the concept of minimum economic size, it seems to be a lower limit for the phosphoric acid route, below which the SSP will be definitely more economic. This limit depends, as usual, to a great extent, on local conditions, but for the purposes of this study it seems reasonable to set it at 200 tpd.

3.3.3.1 Wet-process Phosphoric Acid Manufacture

Phosphoric acid is the basic building block from which all concentrated phosphate fertilizer is made. The overwhelming majority of this acid is manufactured by the wet process method. The process solubilizes the phosphate rock with a strong acid. Sulphuric acid is being by far the most commonly used acid.

Besides the "classic" di-hydrate process, the newer hemihydrate and the modified hemihydrate processes are offered in slightly different proprietary versions by contractors and process owners.

Di-hydrate Process

Phosphate rock is mixed with sulphuric acid to 50-70 % H_2SO_4 concentration in an attack vessel of sufficient size to retain the raw material mixture for several hours. The simplified overall chemical reaction is represented by the following equation:

$$\begin{aligned} &3\ Ca_3(PO_4)_2 + 9\ H_2SO_4 + 18\ H_2O = \\ &= 6\ H_3PO_4 + 9\ CaSO_4 \cdot 2\ H_2O \end{aligned}$$

Following the reaction in the digester, the mixture of phosphoric acid and gypsum is pumped to a filter which mechanically separates the gypsum crystals from the phosphoric acid solution (approximately 30 % P_2O_5 concentration). For each kg of P_2O_5 as phosphoric acid approximately 5 kg of gypsum is produced. Normally the gypsum must be disposed of.

Phosphoric acid produced with a concentration of 26-30 % P_2O_5 is concentrated to 54 % P_2O_5 by evaporation in a shell and tube heat exchanger and a flash chamber under vacuum with high rate internal circulation.

In Fig. 3.3.3/1 the flowsheet of the dyhidrate process can be seen.

Phosphoric Acid Clarification

Phosphoric acid concentrated to a 52-54 % P_2O_5 level becomes a supersaturated solution to a variety of minor acid impurities, namely iron and aluminium phosphates, soluble gypsum and fluosilicates.

The process, which involves only physical treatment of the acid for removal of precipitated solids from 54 % P_2O_5 phosphoric acid is cheaper, than the more complicated and expensive solvent extraction processes. The precipitated impurities are physically separated from the acid by settling and/or centrifugation.

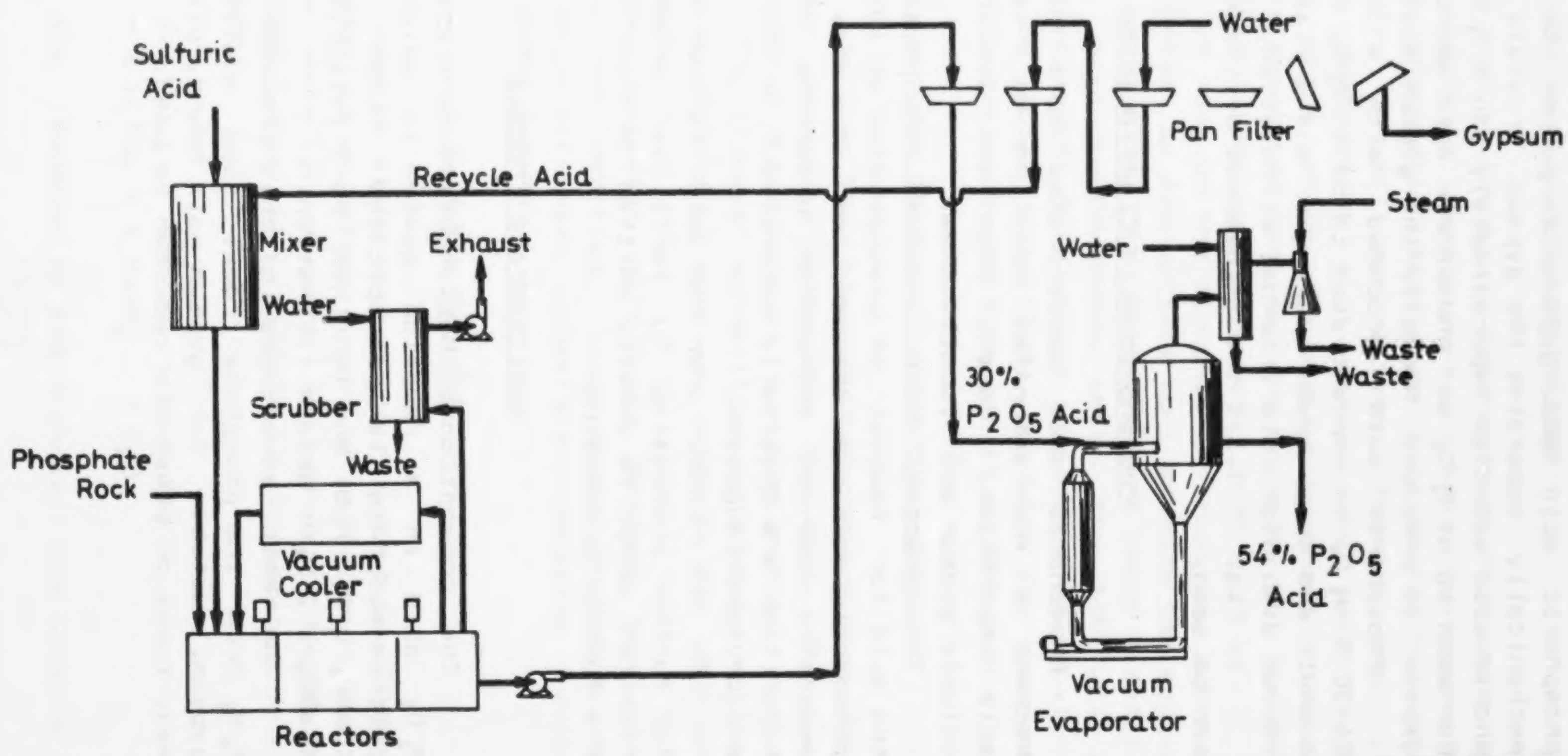
In our case, when the acid is used at the same site for further processing to fertilizer products, the clarification step is usually omitted without diverse effect in the further processing.

Hemi-hydrate Process

The conventional hemi-hydrate process produces 30 % P_2O_5 acid in a reaction system in which the by-product calcium-sulphate is precipitated first as hemi-hydrate ($CaSO_4 \cdot 0{,}5\ H_2O$) and is then re-crystallized to di-hydrate ($CaSO_4 \cdot 2\ H_2O$) before filtration.

The main advantages of this process: high recovery of P_2O_5 from the phosphate rock; good quality of by-product gypsum, suitable for gypsum wall board, plaster and cement; many types of phosphate rock can be used.

Fig. 3. 3. 3/1 Typical Wet-Process Phosphoric Acid Plant.


Sulfuric Acid
Recycle Acid
Mixer
Exhaust
Water
Scrubber
Waste
Phosphate Rock
Vacuum Cooler
Reactors
Water
Pan Filter
Gypsum
Steam
Water
Waste
Waste
30% P_2O_5 Acid
54% P_2O_5 Acid
Vacuum Evaporator

Modified Hemi-hydrate Process

This process is developed from the hemi-hydrate process. In this case the hemi-hydrate is separated from the product acid by filtration before re-crystallization to di-hydrate. The main advantages are that it produces a high strength (45-50 % P_2O_5) acid without concentration, and has a higher efficiency of conversion of phosphate rock.

Evaluation

Table 3.3.3-1 gives the battery limit capital costs and the specific consumption figures for the dihydrate process. The higher recovery of the P_2O_5 in the rock and the better quality of the by-product gypsum of the two other processes must be paid for with higher investment costs, and more severe corrosion problems, but only a few plants were realised, and therefore no exact data are available.

In the following calculations only the classic process will be considered.

For the capacity chosen (200 tpd P_2O_5) the following total investment costs were calculated for the different cases:

	Total	Specific
	investment cost	
		Dollar/t P_2O_5/y million dollar
Developed site		
(West Europe)	23,8	361
Developing site:		
Seaside location	30.3	459
Remote location	35.5	538

The production costs for 1 t of P_2O_5, including also 15 % of R.O.I., will be discussed in the paragraph dealing with final fertilizer products.

Table 3.3.3-1

Battery limit cost and consumption figures for phosphoric acid production

(developed site)

Product: Phosphoric Acid (100 % P_2O_5)

Nominal capacity		200 t/d P_2O_5 million dollar
Battery limit		16,4
Distribution of investment cost:		
- licence, know-how	%	3
- engineering	%	22
- equipment and machinery	%	48
- civil engineering and erection	%	27

Materials and utilities consumption/t P_2O_5 as 54 % acid

- Phosphate Rock (dry) (32,5 % P_2O_5)	t	3,28
- Sulphuric Acid (100 % H_2SO_4)	t	2,95
- Steam (7,5 kg/cm^2 g)	t	2,405
- Electric power	kWh	120,0
- Process Water Make-up	m^3	100,0
- By-Product Fypsum	t	5,5
Labour	men/shift	8

3.3.3.2 Triple Superphosphate (TSP) Manufacture

Triple superphosphate (TSP), with its 46,0 to 48,5 % P_2O_5 content, is a high analysis phosphate fertilizer. As such, it provides transportation economy which can be instrumental in enlarging its share of the phosphatic fertilizer market.

This product has taken over much of the market lost by SSP and accounts for approximately 24 % of the total phosphatic fertilizer market TSP's share of the market for the near future is expected to remain relatively constant primarily because of the tremendous growth of the ammonium phosphates. TSP production unlike SSP, can be most economically produced close to the phosphate rock source. The basic chemical reaction is shown by the following equation:

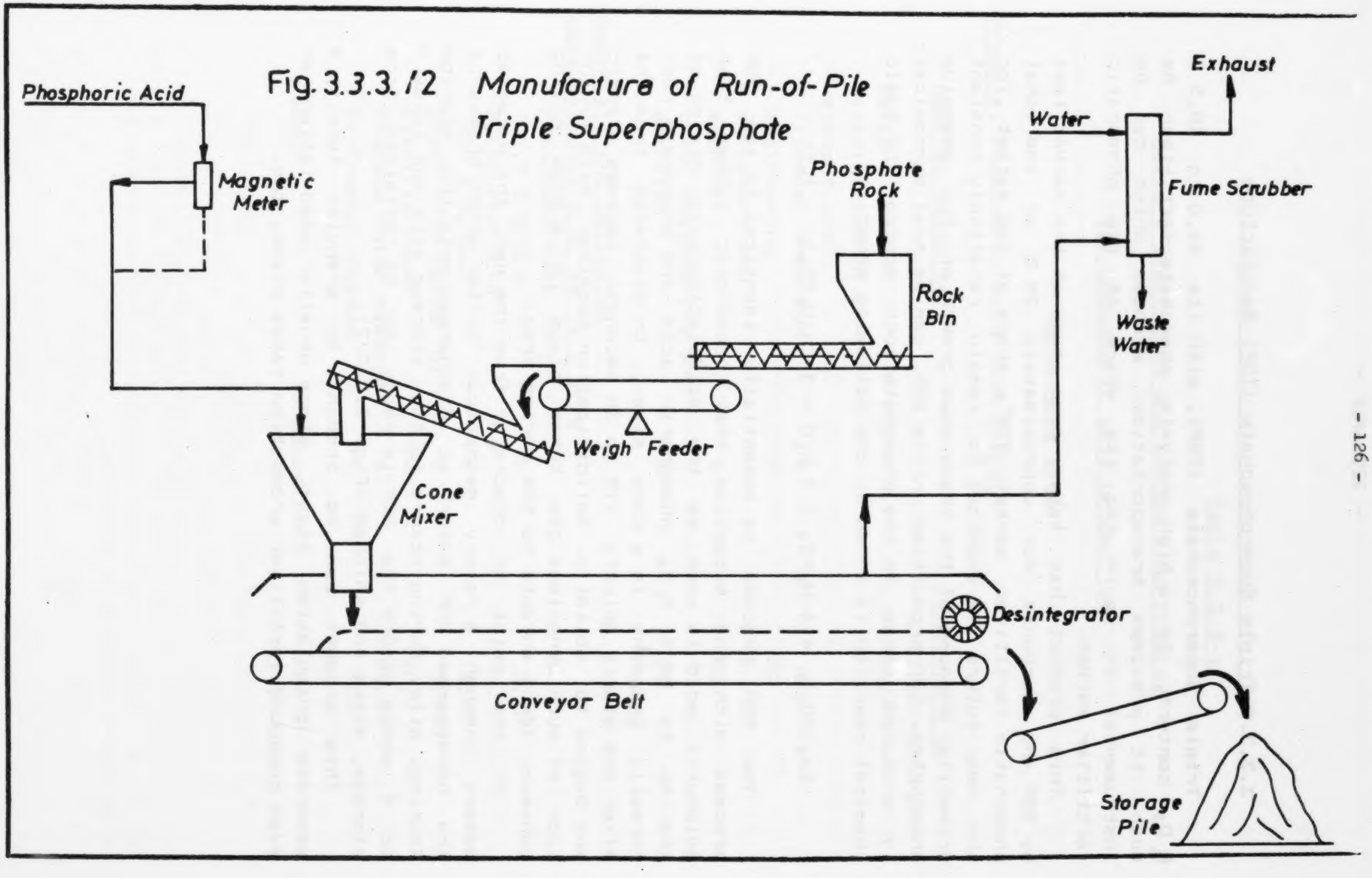
$$Ca_3(PO_4)_2 + 4\ H_3PO_4 + 3\ H_2O = 3\ Ca(H_2PO_4)_2\ .\ H_2O$$

The ROP process is essentially identical to the SSP process with the exception that phosphoric rather than sulphuric acid is used as the acidulating acid. Mixing of the 46 to 54 % P_2O_5 phosphoric acid and phosphate rock normally is done in a cone mixer. On discharge from the mixer the slurry quickly (15 to 30 seconds) becomes plastic and begins to solidify. Solidification together with evolution of much obnoxious gas takes place on a slow moving conveyor (den) enroute to the curing area.

At the point of discharge from the den, the material passes through a rotary mechanical cutter which breaks up the honeycombed ROP before it discharges onto the storage (curing) pile. Curing occurs in the storage pile and takes 2 to 4 weeks before the ROP is ready to be reclaimed from storage, sized and shipped (Fig. 3.3.3/2).

This product can be brought to granular form in a separate granulation plant, where usually ammoniation or even compound fertilizer production takes place, too.

Fig. 3.3.3./2 Manufacture of Run-of-Pile Triple Superphosphate


Phosphoric Acid
Magnetic Meter
Phosphate Rock
Rock Bin
Weigh Feeder
Cone Mixer
Water
Exhaust
Fume Scrubber
Waste Water
Desintegrator
Conveyor Belt
Storage Pile

Direct granulation of Triple Superphosphate

When granular TSP is the desired end product or only low concentration acid is available it is usually preferable to produce it directly. Two general types of direct granulation processes are available: ex-den and slurry granulation.

In the ex-den process after acidulation and denning (similar to the previously described process) drum granulation, drying, screening follows (Fig. 3.3.3/3).

In the slurry process (Fig. 3.3.3/4) forty per cent P_2O_5 acid and ground phosphate rock are mixed together in an agitated tank. The lower strength acid maintains the resultant slurry in a fluid state and allows the chemical reaction to proceed appreciably further toward completion before it solidifies.

After a mixing period of 1 to 2 hours, the slurry is distributed onto recycled dry GTSP material. This distribution and mixing with the dry GTSP takes place in either a pug-mill or rotating drum. Slurry wetted TSP granules then discharge into a rotary drier where the chemical reaction is accelerated and essentially completed by the drier heat while excess water is being evaporated. Dried granules are sized on vibrating screens. Over- and undersize granules are separated for use as recycle material. Product size granules are cooled and conveyed to storage or shipped directly.

Fig. 3.3.3./3 Direct Granulation of Triple Superphosphate

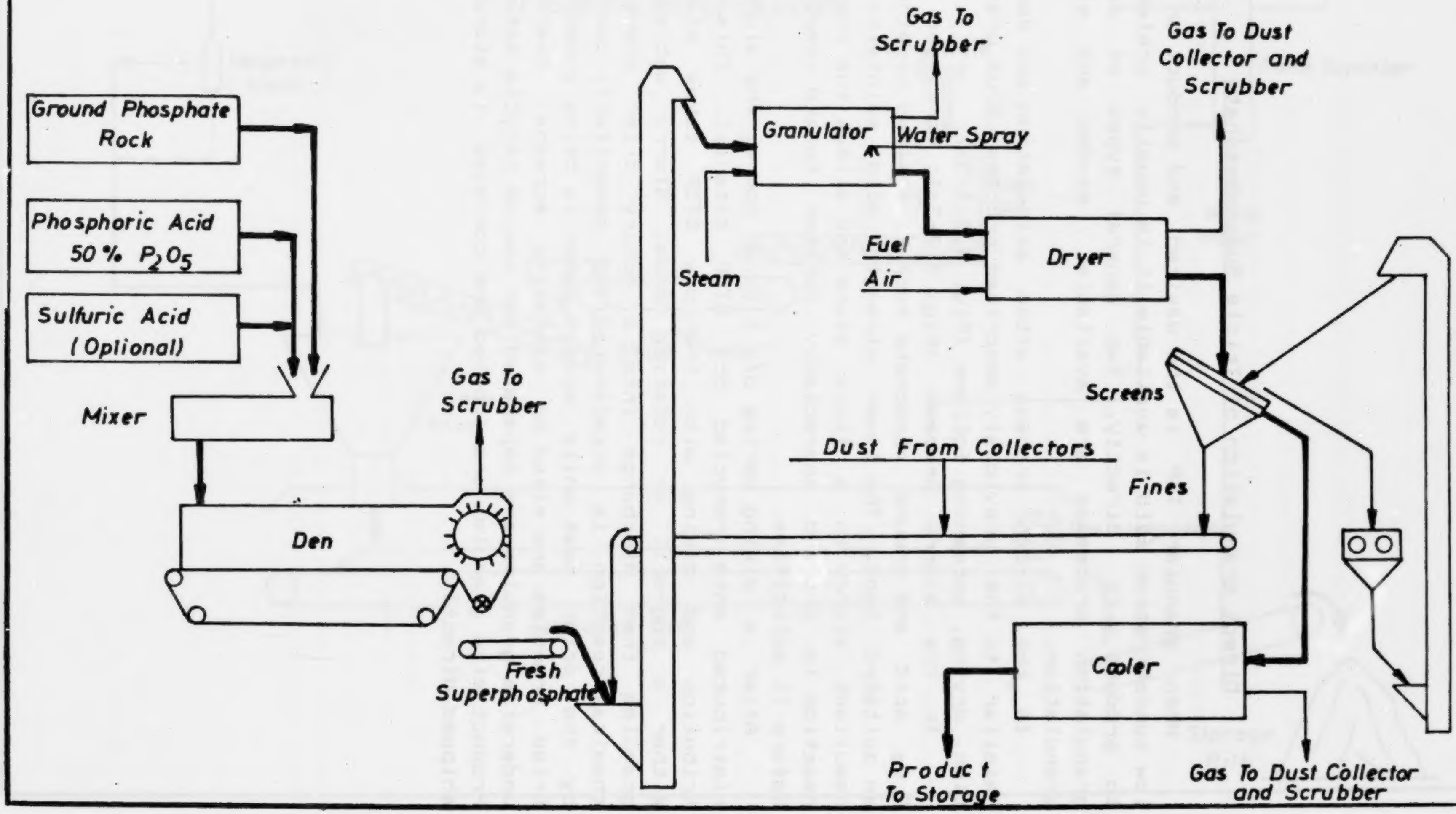
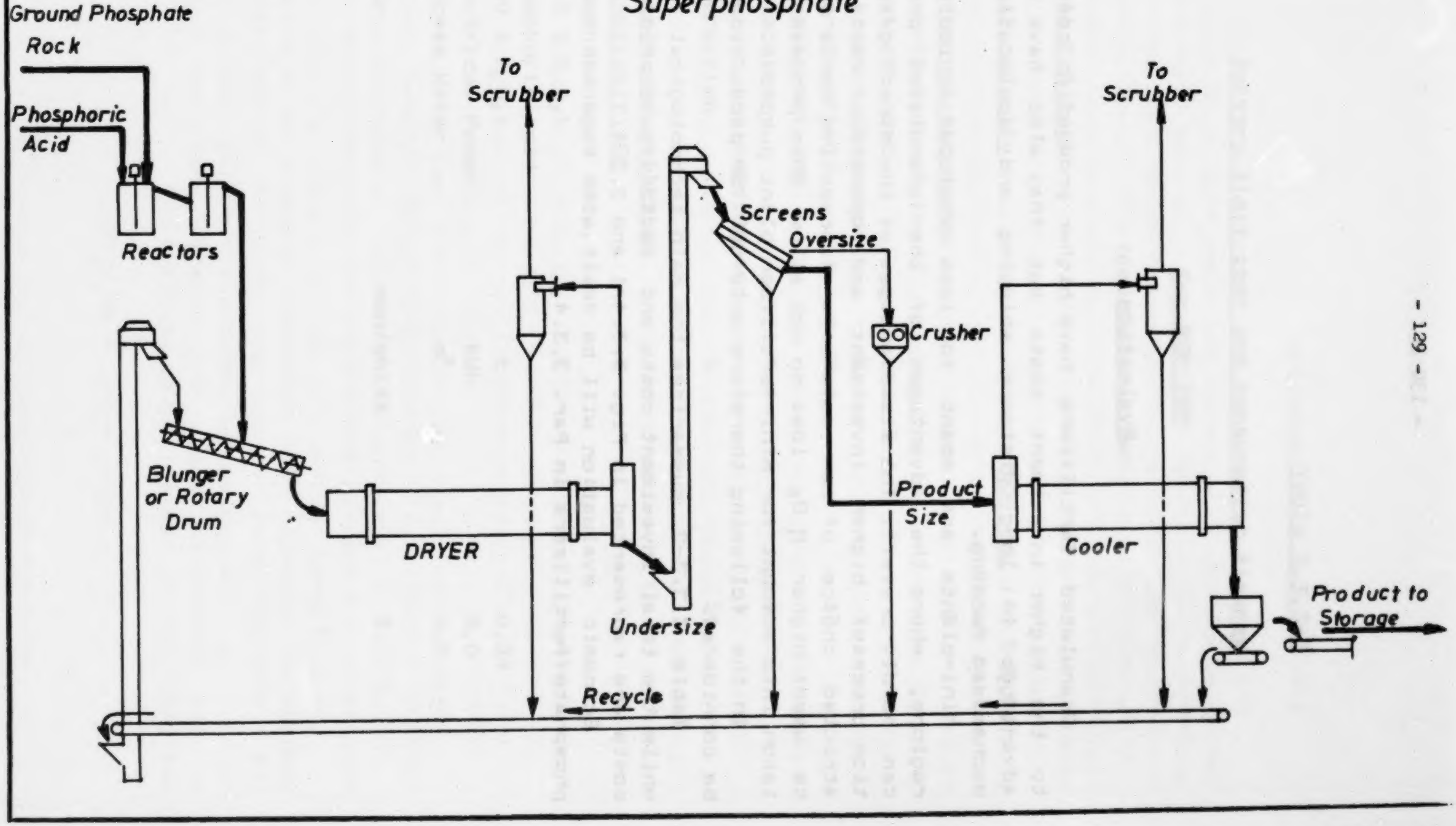

Ground Phosphate Rock
Phosphoric Acid 50 % P_2O_5
Sulfuric Acid (Optional)
Mixer
Den
Gas To Scrubber
Fresh Superphosphate
Steam
Granulator
Gas To Scrubber
Water Spray
Fuel
Air
Dryer
Gas To Dust Collector and Scrubber
Screens
Dust From Collectors
Fines
Cooler
Product To Storage
Gas To Dust Collector and Scrubber

Fig. 3.3.3/4 Slurry Process for the Manufacture of Granular Triple Superphosphate


Ground Phosphate Rock
Phosphoric Acid
Reactors
Blunger or Rotary Drum
To Scrubber
DRYER
Undersize
Screens
Oversize
Crusher
Product Size
To Scrubber
Cooler
Product to Storage
Recycle

Evaluation

Granulated fertilizers have higher production cost due to the higher investment costs but they also have their advantages in long distance shipping and application in mechanised farming.

Mini-plants are meant for less developed agricultural regions, where the advantages of the granulated product can hardly prevail. The disadvantages of the direct granulation process: higher investment and operation costs restricted choice of raw materials (unreactive rocks cannot be used) higher $P_1 O_5$ loss do not allow this process to be taken into account for mini-fertilizer plant purposes.

In the following therefore only ROP TSP production will be considered.

Table 3.3.3-2 summarizes the main technological data, while the total investment costs and factory-gate production costs are represented in Fig. 3.3.4/1 and 3.3.4/3.

Economic evaluation will be dealt with together for all phosphate fertilizers in Par. 3.3.4.

Table 3.3.3-2

Battery limit cost and consumption figures

for ROP TSP

(developed site)

TSP (46 % P_2O_5)

Nominal capacity		500 t/d (46 % P_2O_5)
		million dollar
Battery limit cost		3,5
Distribution of investment cost		
- licence, know-how	%	3
- engineering	%	17
- equipment and machinery	%	46
- civil engineering and erection	%	34
Materials and utilities consumption/t TSP		
- Phosphate Rock (dry, 32,5 % P_2O_5)	t	0,41
- Phosphoric acid (100 % P_2O_5)	t	0,34
- Electrical Power	kWh	8,0
- Process Water	m^3	2,0
Labour	men/shift	5

3.3.3.3 Ammonium Phosphates

The ammonium phosphate fertilizers are highly concentrated sources of watersoluble plant food which have had a spectacular agricultural acceptance in the past twenty years. Production capacity of di-ammonium phosphate (DAP) has increased at a compound rate of 19,8 % annually over the last ten years. The popularity of the ammonium phosphates results from a combination of factors.

These include the ready adaptability of the production processes to even increasing single-plant capacities with their associated lower production costs; favourable physical characteristics which facilitate storage, handling, shipping and soil application; compatibility with all common fertilizer materials; transportation economies effected by the shipment of high nitrogen (18 %) and phosphate (46 % P_2O_5) nutrient content. Such impressive number of plus factors insure that ammonium phosphate processing will continue to be an important segment of the fertilizer industry.

Ammonium phosphate fertilizers include a variety of different formulations which vary only in the amounts of nitrogen and phosphate present. The most important ammonium phosphate fertilizers in use are:

MAP	DAP
11-48-0	16-48-0
12-52-0	18-46-0
11-55-0	

Diammonium phosphate formulations are produced in the largest tonnages with DAP (18-46-0) being the most dominant.

The two primary raw materials used to produce ammonium phosphates are ammonia and wet process phosphoric acid.

As mentioned above, the various grades vary only in the amounts of nitrogen and phosphate present. It is primarily the nitrogen that varies and this is accomplished by controlling the degree of ammoniation during neutralization of the phosphoric acid. The chemical reactions involved are indicated by the following equation:

$$H_3PO_4 + NH_3 = NH_4H_2PO_4$$

The processing steps are essentially identical to those described in the triple superphosphate GTSP process (FIG. 3.3.3/5). Ammonia, either gaseous or liquid, is reacted with 30 to 40 % P_2O_5 phosphoric acid in a vertical cylindrical vessel which may or may not have mechanical agitation. The resultant slurry is then pumped to a mixer where it is distributed onto dry recycled material.

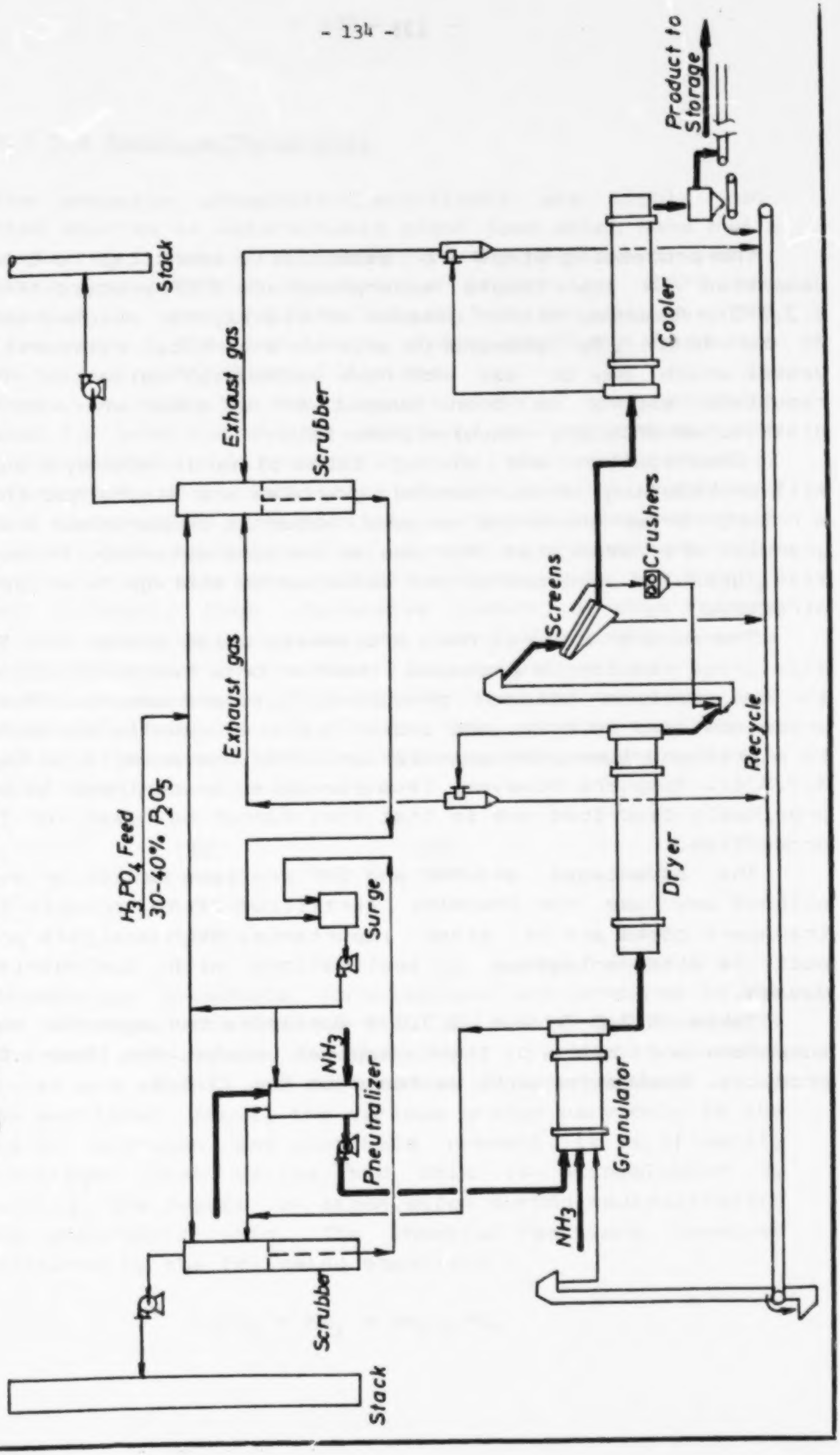
Distribution and mixing takes place in either a pugmill or rotating drum. Wetted granules are discharged into a rotary drier where the excess water is evaporated. Dried granules are separated for use as recycle material. Product size granules are cooled and conveyed to storage or shipped directly.

There are several new processes, using either the TVA pipe cross reactor, a pressure reactor or a two-fluid nozzle for the reaction between phosphoric acid and ammonia. These processes need no drier and cooler and are usually connected to a prilling tower for granulation. (See one example in Fig. 3.3.3/6). They are however, less flexible: in contrast to the previously described one in that they cannot be used for TSP production.

The advantages of MAP and DAP are less marked or even without any use for the mini fertilizer plant concept: low transport costs are of minor importance, high analysis product is disadvantageous in applications with low nutrient dosage.

Table 3.3.3-3 and 3.3.3-4 summarize the specific consumption and battery limit capital costs for these two products. Evaluation will be found in Par. 3.3.4.

Fig. 3.3.3./5 Diammonium Phosphate Process


Stack
Scrubber
Pneutralizer
NH_3
Surge
H_3PO_4 Feed
30-40% P_2O_5
Exhaust gas
Scrubber
Exhaust gas
Stack
NH_3
Granulator
Dryer
Recycle
Screens
Crushers
Cooler
Product to Storage

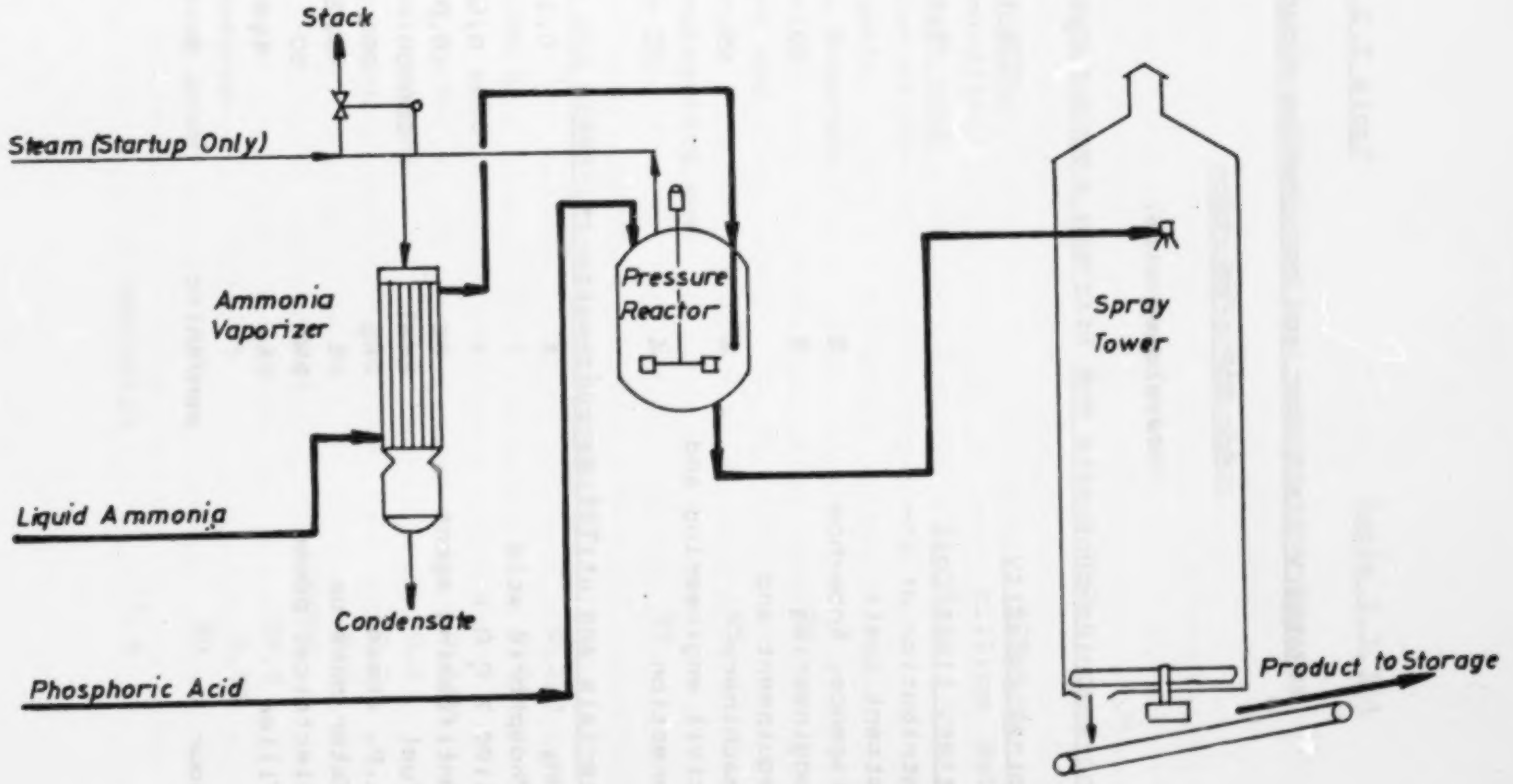


Fig. 3.3.3/6 MAP Process

Stack
Steam (Startup Only)
Ammonia Vaporizer
Liquid Ammonia
Condensate
Phosphoric Acid
Pressure Reactor
Spray Tower
Product to Storage

Table 3.3.3-3

Battery limit cost and consumption figures for MAP production

(developed site)

Mono-ammonium-phosphate MAP (1/2 % N + 52 % $P_1 O_5$)

Nominal capacity		375 t/d
		million dollar
Battery limit cost		5,6
Distribution of investment cost:		
- licence, know-how	%	3
- engineering	%	20
- equipment and machinery	%	45
- civil engineering and erection	%	32
Materials and utilities consumption/t MAP		
- NH_3	t	0,148
- Phosphoric acid (100 % $P_1 O_5$)	t	0,53
- Antifoaming agent	kg	0,05
- Fuel	kcal	200000
- L.P. steam	kg	25
- Water make-up	t	0,2
- Electrical power	kWh	30
- Filler	kg	1,3
Labour	men/shift	5

Table 3.3.3-4

Battery limit cost and consumption figures for DAP production

(developed site)

Di-ammonium-phosphate, DAP (18 % N + 46 % P_2O_5)

Nominal capacity		425 t/d
		million dollar
Battery limit cost		5,6
Distribution of investment cost:		
- licence, know-how	%	3
- engineering	%	20
- equipment and machinery	%	45
- civil engineering and erection	%	32
Materials and utilities consumption/t DAP		
- NH_3	t	0,223
- H_2SO_4 (100 %)	t	0,04
- Phosphoric acid (100 % P_2O_5)	t	0,469
- Antifoaming agent	kg	0,1
- Coating agent	kg	10,0
- Coating oil	kg	5,0
- Fuel	kcal	100000
- L.P. steam	kg	20,0
- Water make-up	t	0,35
- Electrical power	kWh	30
Labour	men/shift	5

3.3.3.4 Superphosphoric Acid and Ammonium Polyphosphates

Superphosphoric acid is produced by concentrating merchant-grade ortophosphoric acid (54 % P_2O_5) in a vacuum or atmospheric concentrator. The superphosphoric acid usually contains about 68 % to 70 % total P_2O_5, of which 20 % to 35 % is present as polyphosphate. Essentially all of the polyphosphoric acid content of wet-process superphosphoric acid is in the form of pyrophosphate; the remaining phosphate is present as ortophosphoric acid.

Conversion to superphosphoric acid increases the cost, but with long shipping distances generates freight savings that reduce or eliminate this disadvantage. This acid is very viscous when cold and must be kept constantly at a temperature of 60° C at all times during transport and storage so as to keep it sufficiently fluid.

The superphosphoric acid is used first of all for the production of ammonium polyphosphate. Nowadays, a number of plants use the pipe reactor process (developed by TVA) to manufacture this product.

The superphosphoric acid is weighed upon arrival, its temperature is adjusted and then is sent to the unit store, which is also kept at a constant temperature of about 60° C. The superphosphoric acid pumped at a metered rate from storage to neutralization.

One kind of pipe reactor processes uses a separate mix tank and an evaporative cooler. The mix tank is used for mixing the hot melt from the pipe reactor with the recirculating liquid. By having a separate mix tank it is possible to maintain a high liquid temperature of 82° C, which enhances mixing of the melt in a liquid form and also provides excellent means of evaporating and superheating the anhydrous ammonia used in the pipe reactor.

The plants with the separate mix tank usually produce an ammonium polyphosphate liquid of slightly higher polyphosphate content than the other methods. Probably one reason this occurs is because of the high temperature of the ammonia used in the pipe reactor.

Ammonia that is not added to the pipe reactor is usually added as liquid ammonia to the mix tank. Usually about 60 % of the ammonia is added to the pipe reactor and 40 % to the mix tank. This tank is equipped with a small scrubber in which cooled ammonium polyphosphate is used to scrub the extra gases from the mix tank.

A considerable amount of 10-34-0 is used for direct application, but most of the ammonium polyphosphate liquids (10-34-0 or 11-37-0) are used in small mix plants to produce NPK mixtures. The ammonium polyphosphate can be applicated in solid form, too.

Equipment used to apply liquid fertilizers are rather expensive, require a highly sophisticated agricultural background, therefore, the application of this kind of fertilizers in the developing countries, for the moment, is not a real possibility. Therefore no economic evaluation was attempted.

3.3.4 Economic evaluation of phosphate fertilizers

Capacity

According to the 3.3 Introduction section, only two selected capacities for H_2SO_4 and one size for all other products were examined. Since scale-up has no effect on the process, specific consumption figures remain essentially the same for all capacities in the mini-plant range and battery limit investment figures can be extrapolated by the usual formula with a 0,8 as exponent. Therefore the figures computed for the sizes selected will only be improved, when bigger mini-plants will be considered.

For the sizes selected Figs. 3.3.4/1 and 3.3.4/2 summarize the total and specific investment costs for different locations. Fig. 3.3.4/3 give the production costs for the same alternatives in function of the phosphate rock price. Fig. 3.3.4/4 shows the farm gate prices for the same cases compared to the imported products. Calculation methods are identical with those mentioned for ammonia. Details can be found in Annex 3/1.

From the diagrams it is obvious that the farm-gate price of the mini-plant product will be in every case by far the most advantageous.

Although investment and factory gate production costs were not calculated for big size plants, the import prices used as reference level for farm-gate price comparison reflect the cost level of the big production units, since exported good come mainly from these plants.

The very big differences between SSP and TSP production underline the conclusion that for mini-plants the right product is SSP.

The more sophisticated MAP and DAP involves even higher investment costs and seem not very appropriate for mini-plants in developing countries.

NPK plants can form a viable alternative only if ammonia, nitric acid and phosphate processing facilities are on the same site - a case seldom encountered.

Fig..3.3.4/1. **Total investment costs of – phosphate complexes**

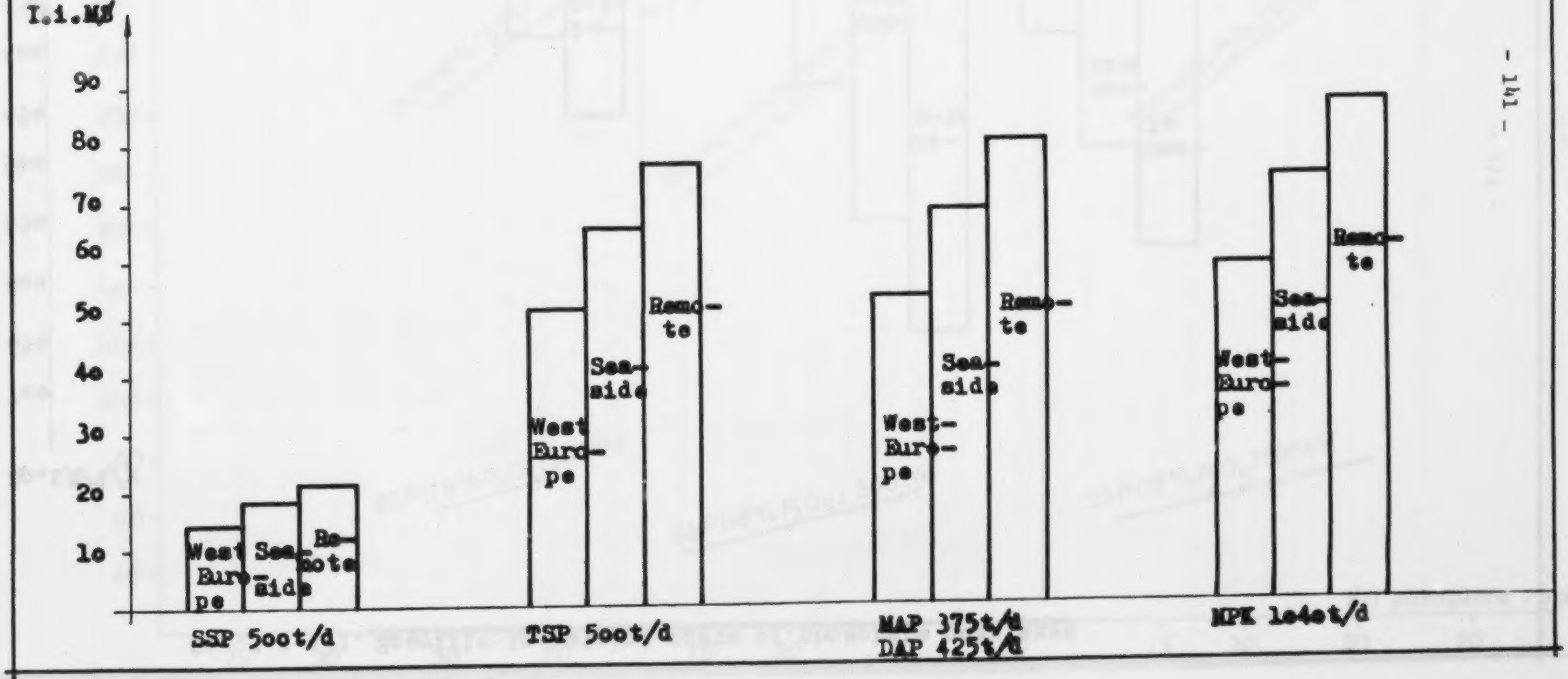


Fig.3.3.4/2. Specific investment costs of phosphate complexes

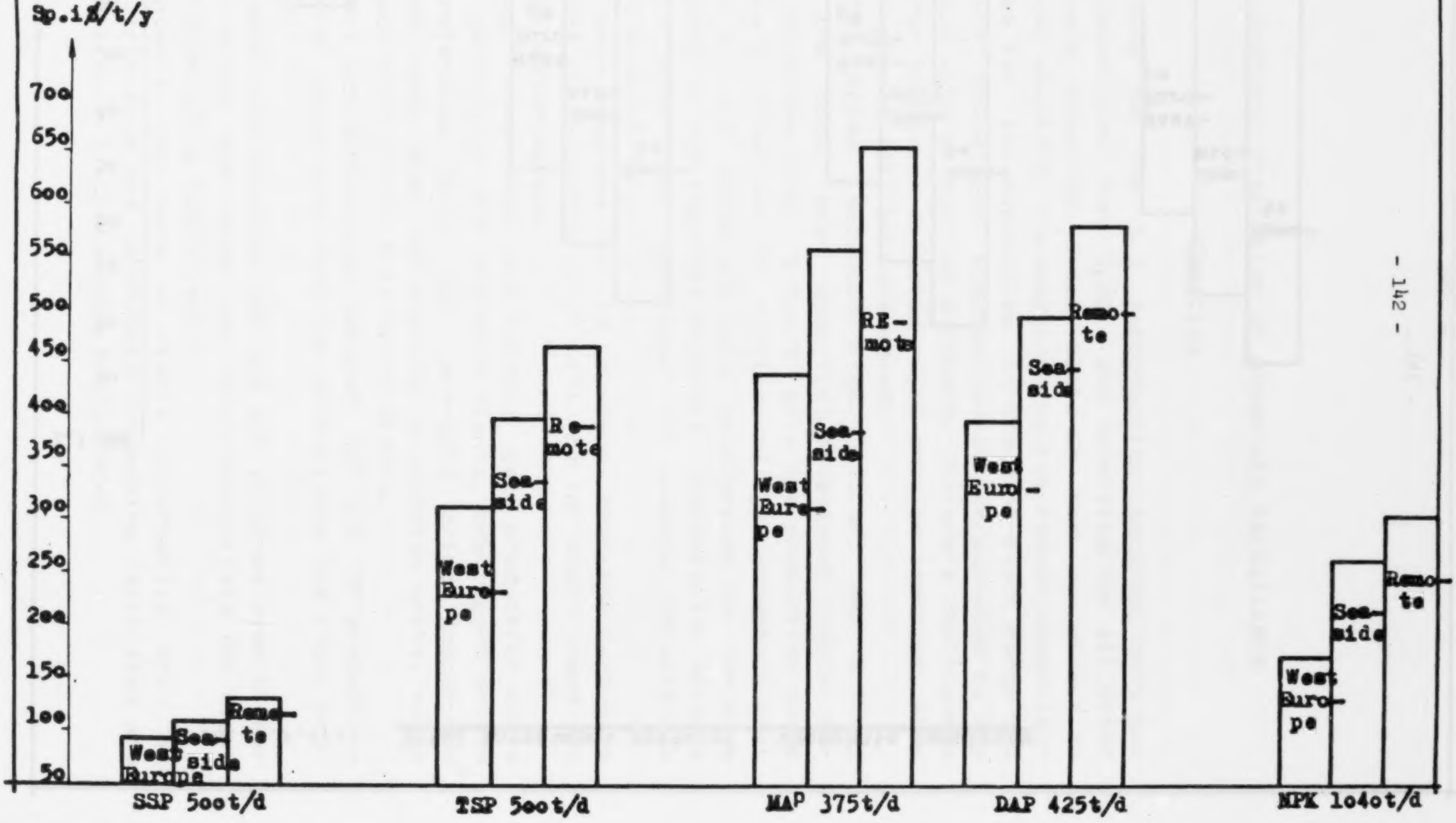
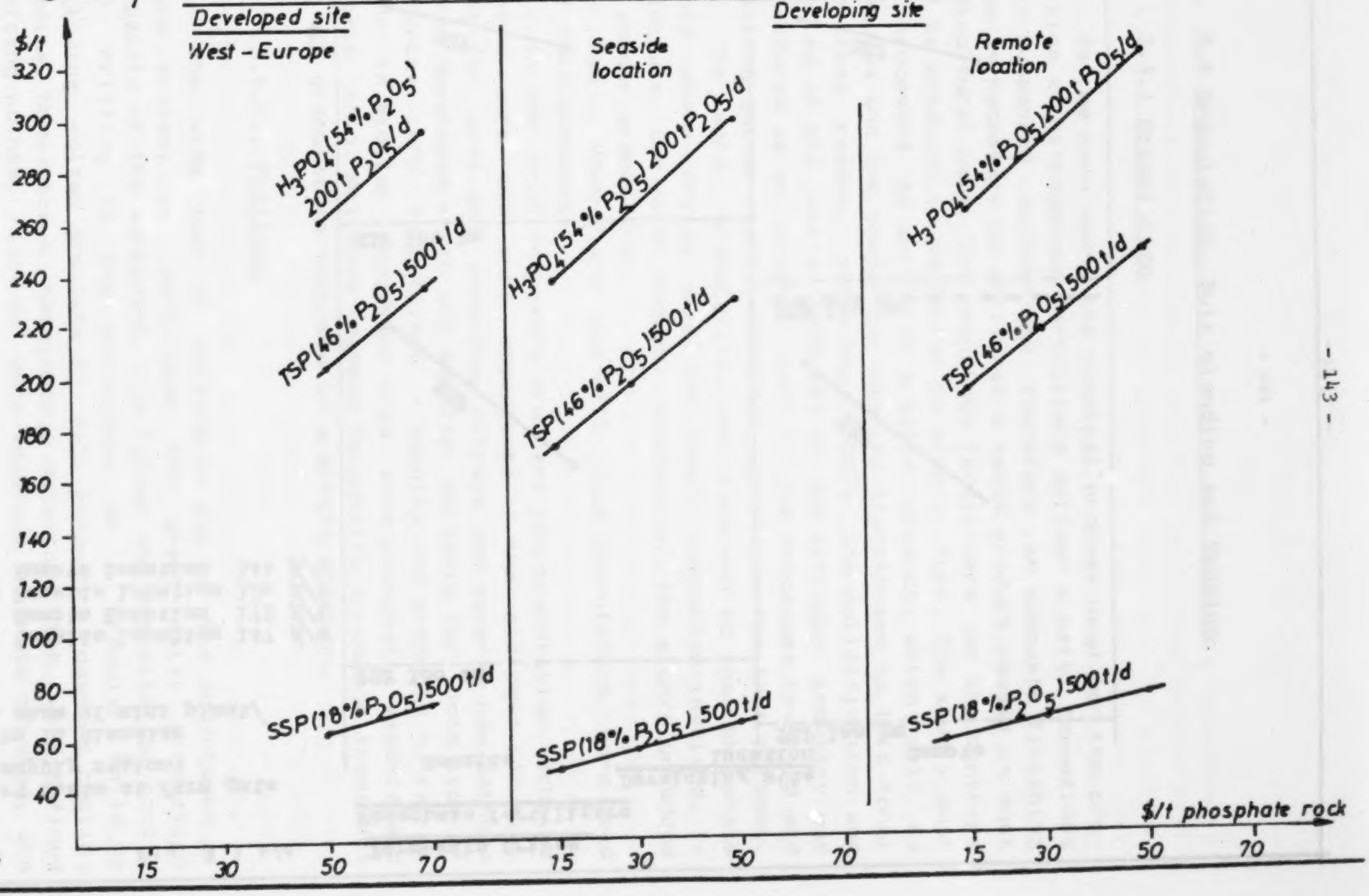


Fig. 3.34/3 Product value at factory gate: phosphoric acid, SSP, TSP



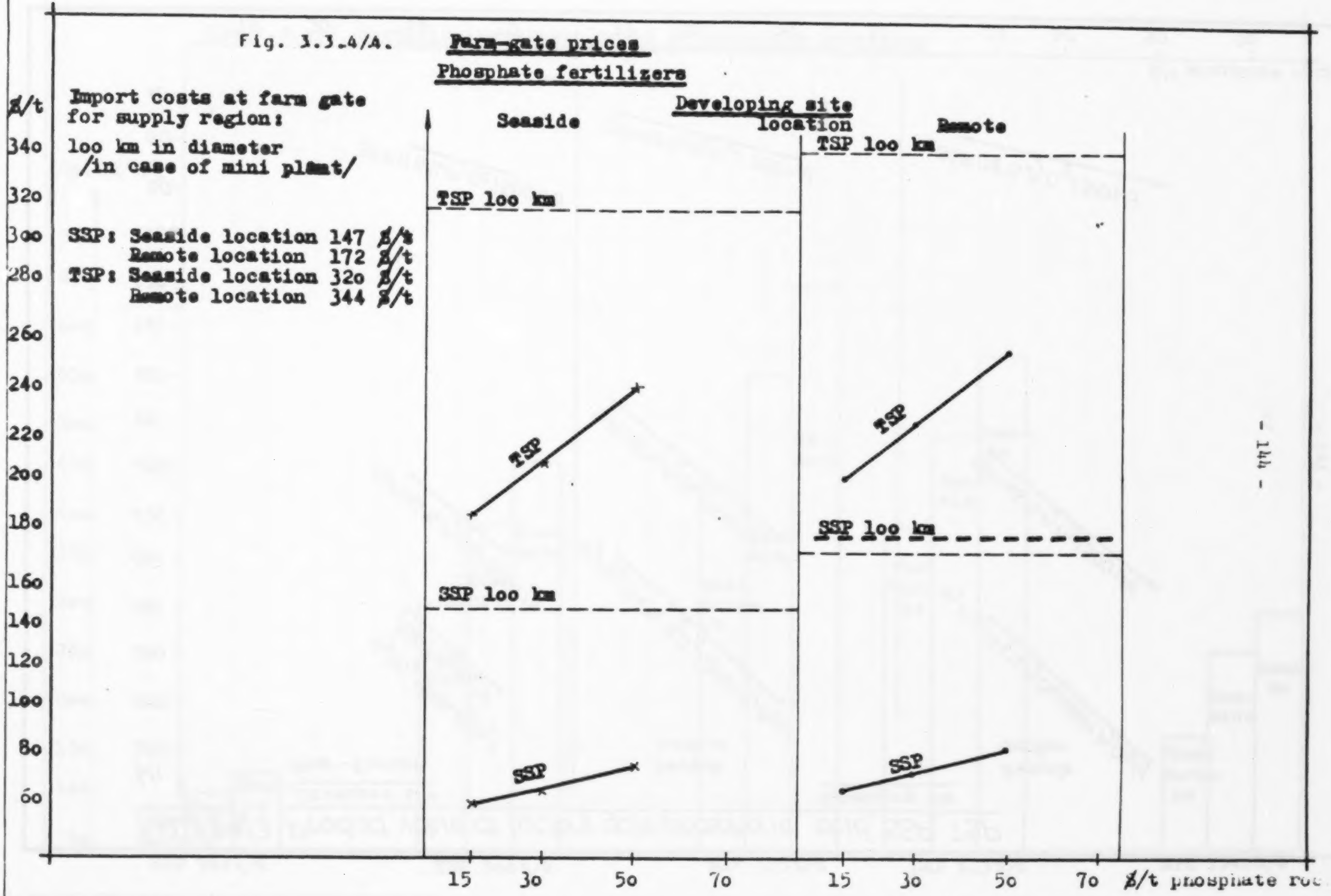


Fig. 3.3.4/A. **Farm-gate prices**

Phosphate fertilizers

3.4 Granulation, Bulk blending and Bagging

3.4.1 Granulation

As we have seen, the chemical process used for the production of nitrogenous fertilizers deliver a melt (sometimes with suspended solids) and therefore an adequate finishing step is necessary to arrive at a solid product needed in most agricultural uses. The phosphate fertilizers on the contrary can be produced in powder or in slurry form. The slurry must be processed to arrive at a solid product, which will be granules and the powder can also be transformed to this form. For that reason, since the 1950's the solidification and cooling of the melts produced in the nitrogen industry was considered as an integral part of the processes involved and prilling gained nearly universal acceptance for this purpose.

The word, granulation, was reserved to the phosphate field where drying was the basic operation involved, to eliminate the water content carried in the slurry or added in powder granulation.

Pan-, drum- and pug-mill type granulators were used for this purposes.

In the last few years drum and pan granulation technics gained more and more acceptance in the nitrogen industry both for urea and ammonium nitrate and several new methods were developed which are equally suitable for both type of products. NPK fertilizers - equally new products - can be made in similar equipment from some phosphate, ammonia and nitric acid. All this seemed to justify a common treatment of all granulation technics in a single chapter.

3.4.1.1 Prilling

The wide use of priling is due to the advantages of this system, in particular the great daily production capacity of the equipment, low labour and exploitation costs.

Prilling is the production of a granular solid by allowing molten droplets to fall through a gaseous cooling medium. Non-viscous homogeneous materials with well-defined melting points, such as pure ammonium nitrate or urea, are very easily prilled.

To obtain hard and non-porous prills, the water content must be reduced below 0,5 % as otherwise a porous, low-density product results which is troublesome in storage. Jets of free-falling molten materials are broken up to droplets by the air. The droplets begin to solidify as they fall through the cooling medium. The crystallization starts at the surface and progress gradually to the inside.

The prilling device and melt temperature must be carefully controlled. The retention time in the prilling tower is also important factor. The proper design of the tower height and cooling air flow are essential to obtain completely hard prills at the bottom. The still hot prills arriving at the bottom must be collected and transported to the finishing, and cooling may also be needed.

The prilling tower itself is a structure supporting the prilling equipment placed on the top, together with fans providing the necessary air stream. The main characteristics of the tower are the height determining the retention time, the cross-section fixing the capacity and the air stream.

The not completely satisfactory granulometric composition is the drawback of this system. Prills are relatively small; in practice most are around 1 mm and only a small proportion arrive near to 2 mm.

Prilling is very advantageous for big capacities. At the lower end specific investment cost begin to rise to such an extent that other granulation technics become more advantageous.

3.4.1.2 Pan Granulator

This principle, which had been widely used in the pharmaceutical industry was developed for superphosphate granulation and was extensively used in the phosphate industry.

Number of companies made considerable improvements, and the process lends itself for making granular ammonium nitrate and urea. Granulation is accomplished by spraying hot concentrated melt of fertilizer salts onto a cascading bed of recycle material in a pan granulator.

The granulated product is cooled and is sized in conventional equipment. The oversize fraction from the screen is crushed and returned with the undersize fraction for use as recycle material. The correct size product is treated with an appropriate conditioning agent and sent to store.

Critical features of the pan granulator for best operation include slope, rotational speed, location of spray, concentration, and the amount, particle size and temperature of the recycle material.

3.4.1.3 Drum Granulator

The classic drum granulator consists of a slightly inclined rotary cylinder with retaining rings at each end and with appropriate material structures.

The basic materials must be well mixed before entering the drum, which serves only to form the granules; these are rounded at the bottom of the drum by their contact with each other. The speed of rotation of a drum granulator must be slow enough for the granules not to be carried around by centrifugal force since the principle of this system is that the granules should move relative to the drum.

Depending on the residence time required, drum granulators may be mounted with a downward slope up to 3°.

Drying and cooling are both needed after granulation, so a typical granulator train consists of a drum with two sections, the first serving for mixing and chemical reaction, the second for granulation, followed by a drier and cooler both of drum type.

A basic feature of the drum granulator system is the great amount of recycle material. Not only over- and undersize material, but a given part of the product must be recycled depending on the water content of the input materials for optimum granulation drying conditions.

This process can be combined with ammoniation of phosphates (SSP or TSP), NPK fertilizer manufacture etc., as well as for granulation of SSP or TSP powder. Fig 3.4/1-3 represents the respective flowsheets for TSP granulation, ammoniation and NPK manufacturing.

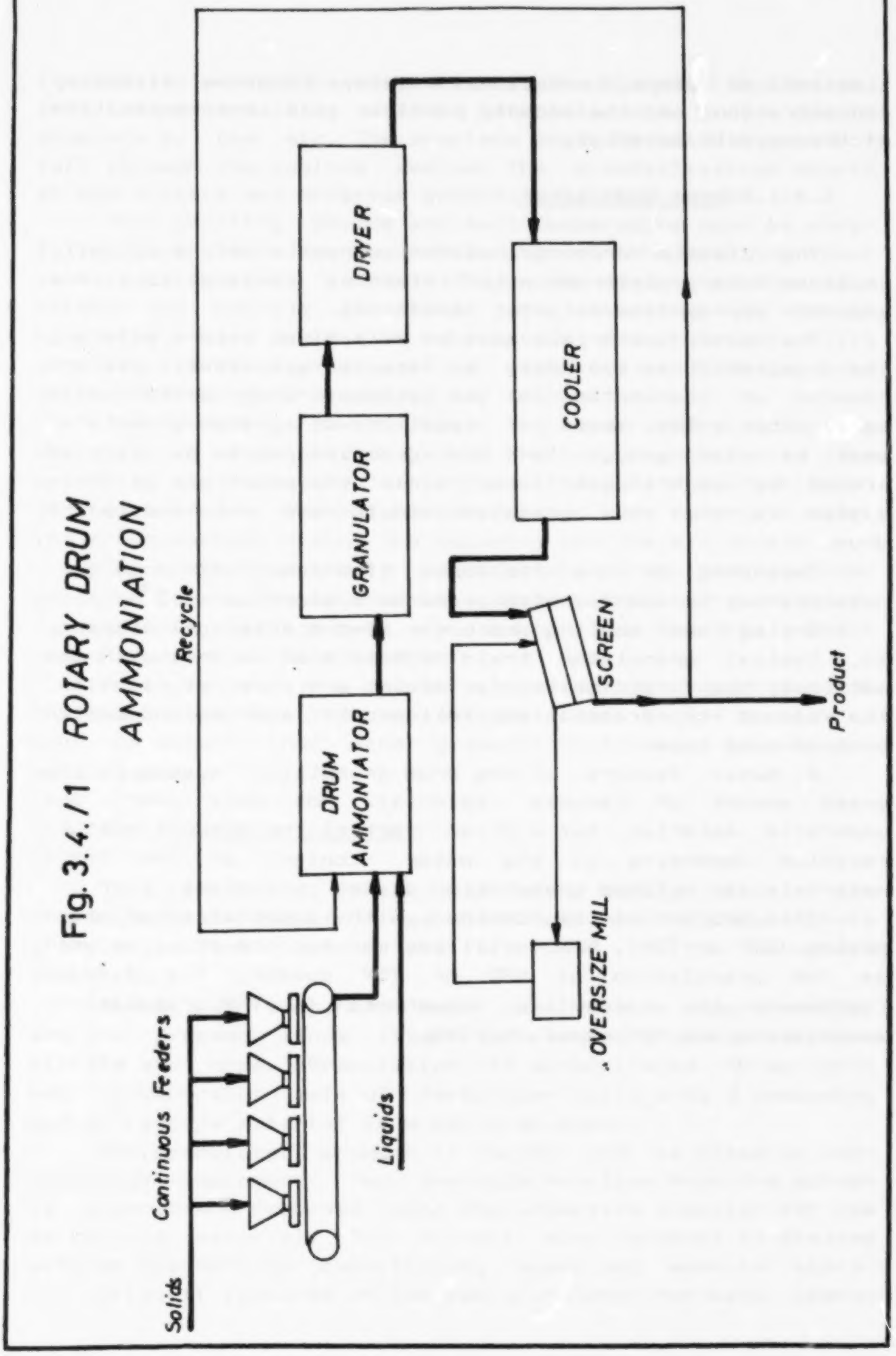

Solids
Continuous Feeders
Liquids
Recycle
DRUM AMMONIATOR
GRANULATOR
DRYER
COOLER
SCREEN
OVERSIZE MILL
Product

Fig. 3.4./1 ROTARY DRUM AMMONIATION

Fig. 3.4./2 Granulation of Cured Run-of-Pile Triple Superphosphate

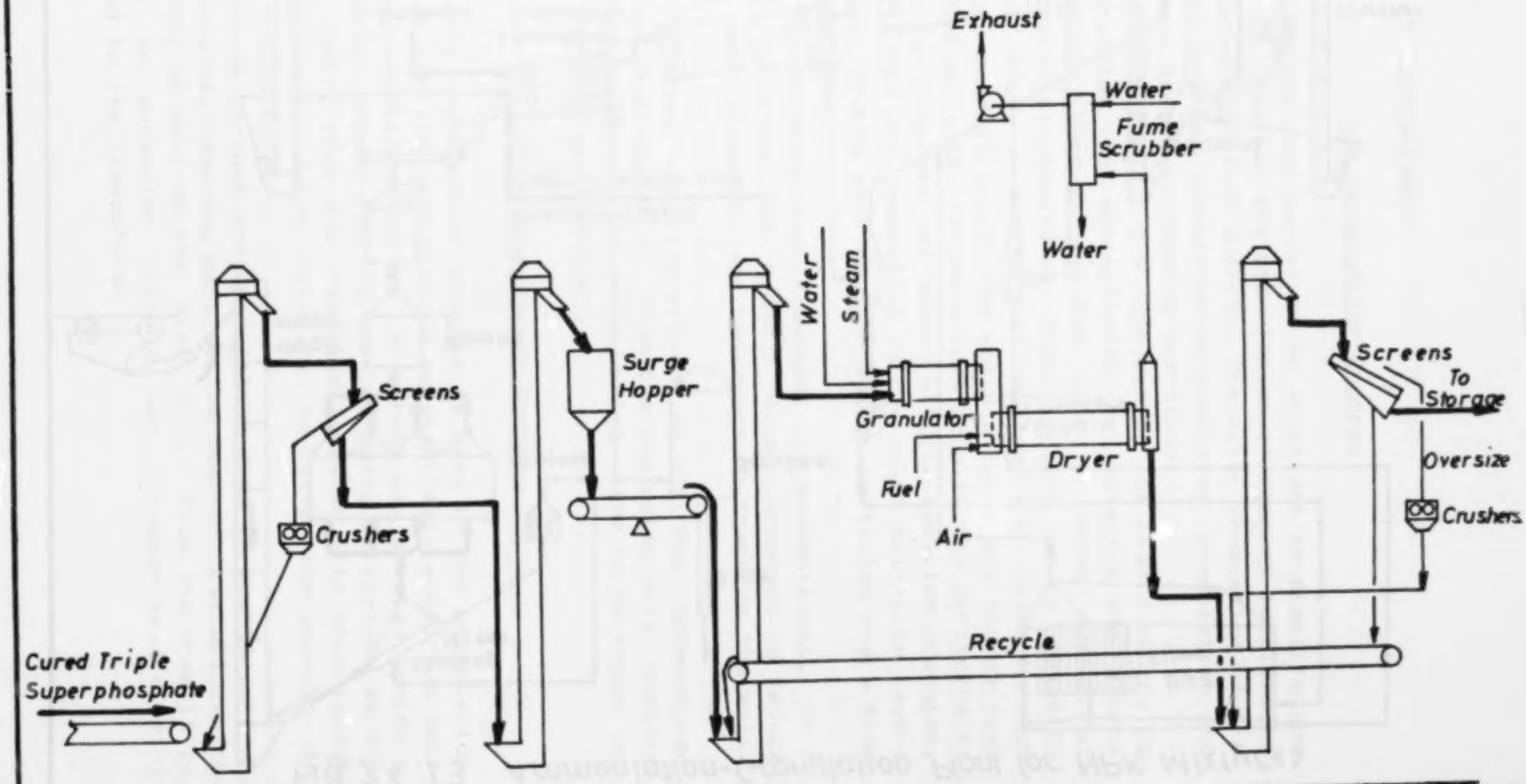
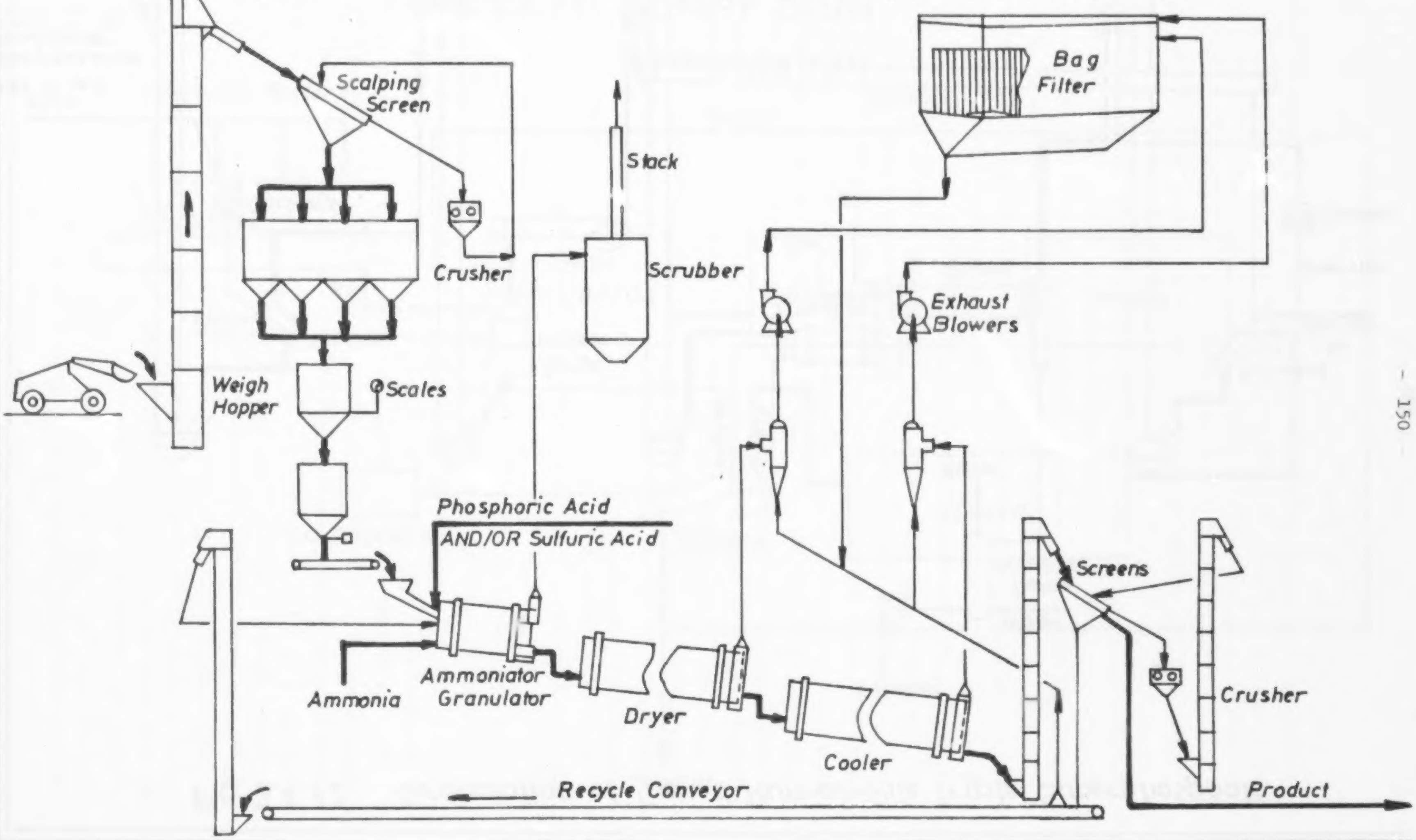

Exhaust
Water
Fume Scrubber
Water
Water
Steam
Surge Hopper
Screens
Crushers
Granulator
Fuel
Air
Dryer
Screens
To Storage
Oversize
Crushers
Recycle
Cured Triple Superphosphate

Fig. 3.4 ./3 *Ammoniation-Granulation Plant for NPK Mixtures*


Scalping Screen
Crusher
Weigh Hopper
Scales
Stack
Scrubber
Bag Filter
Exhaust Blowers
Phosphoric Acid
AND/OR Sulfuric Acid
Ammonia
Ammoniator Granulator
Dryer
Cooler
Screens
Crusher
Recycle Conveyor
Product

3.4.1.4 Spherodizer

Hot Spherodizer Process

The process was conceived in an effort to simplify the processes in use for the granulation of complex fertilizers and to improve product quality. The major innovation of the spherodizer process consisted of combining granulation and drying into a single processing operation.

By this process, the conversion of liquid slurry to uniform granules is accomplished by spraying the slurry under pressure through nozzles onto a dense curtain of recycled material cascading from lifters in a rotating cylindrical drum. A stream of heated air flows through the drum co-currently with the solid recycle and the sprayed slurry, coming into intimate contact with the particles to be dried. As droplets of slurry hit the recycled granules, water is flashed off, resulting in new onion skin-like layers of material around each of the solid particles every time they are cascaded.

The remainder of the flowsheet is conventional, with screens to separate the product size, crushers to reduce oversize, and elevators and conveyors to transfer the solid materials.

This process was identified as the "Hot Spherodizer Process" to distinguish it from the one using only cooling air for the granulation of melts, which came to be known as the "Cold Spherodizer Process".

Cold Spherodizer Process

The cold spherodizer process is used in the granulation of ammonium nitrate and urea. A substantially anhydrous melt of either ammonium nitrate or urea is sprayed inside a rotating drum onto a rolling bed of solid particles. As the particles roll, they are repeatedly coated with thin layers of liquid melt, which solidify to give the granule an onion-skin structure.

Air flows through the granulation drum in countercurrent to the granules, removing part of the heat of crystallization of the melt, as well as the fine dust. From the drum it is drawn by an exhauster into a wet scrubber before being discharged to the atmosphere.

3.4.1.5 Pugmill

Mixing and granulation in the same equipment is achieved with a double-shaft granulating screw, called pugmill or blunger. The pugmill is followed by a drier, a cooler and screening.

The crushed oversize product is combined with the undersize product and the mixture is recirculated in a controlled ratio in the cold and dry state to the pugmill. The hot fresh slurry mixed with the recycle product gives soft balls with a moisture content of 3-6 %, depending on the recycle ratio and the amount of water in the slurry.

Only partial crystallization and no moisture elimination takes place in the pugmill and therefore the soft balls must be dried in a rotary drum by hot air, cooled in a cooling drum and then screened.

Evaluation

For the mini-plant concept, due to the conditions prevailing in the regions favourable for the small size, the pan, respectively drum granulation seems more appropriate for nitrogenous fertilizers, due to the relatively high investment cost of the prilling power. For phosphate fertilizers it seems appropriate to start with non-granulated material (powder) and switch over only at a given degree of agricultural mechanisation to the granulated form.

3.4.2 Bulk Blending

General

Where granulated fertilizers should be blended, bulk blending is very advantageous. The process is usually of the batch type, with a minimal capacity of 1 to 2 tons per batch. The mixing time is 2 to 3 minutes, consequently as much as 10 to 20 tons per hour easily can be mixed. Depending on the working days of a year (approximately 100 days) the production will be about 10000 to 20000 tons per year.

Process Description

The material commonly used in bulk blending are ammonium nitrate, ammonium sulphate, triple superphosphate, diammonium phosphate and potassium chloride. Other materials sometimes used are urea, ammonium phosphate nitrate (30-10-0), ammonium phosphate sulphate (16-20-0) and normal superphosphate.

The materials should be closely sized, dry enough to prevent caking in storage, and sufficiently strong to prevent fragmentation in handling.

Type of mixers and layout of storage, conveying and mixing facilities vary widely, so much that probably no two plants are alike. Since the plants are small and quite often built on a very limited budget, they tend to be homemade.

Mixing is usually of the batch type, with materials introduced one at a time from a weight hopper. Usual capacity is 1 to 2 tons per batch and mixing time is 2 to 3 minutes. As much as 15 tons per hour can be mixed even in a one-ton mixer. In some cases the entire cycle of weighing, mixing and discharging is done automatically.

Mixers are mainly of rotating drum type, but various other types including ribbon mixers, mixing screws, gravity mixing towers and a volumetric metering device are used. The volumetric metering device is a continuous type in which materials are feeding by gravity through adjustable gates onto a common belt. The materials mix as they flow into the receiving hopper and in the following cut-screw conveyor.

Evaluation of Bulk Blending in the Distribution System

Until the emergence of bulk blending in the early 1960's, mainly in the USA, traditional distribution of fertilizer involved the movement of bagged fertilizers, from medium sized production plants producing between 25000 and 200000 tons per year of mixed fertilizers, to farm buyers, through general retail farm supply organizations.

However, in the early 1960's the advantage of bulk handling of fertilizers became apparent and the emergence of bulk blending developed quickly.

In bulk blending, a few basic high analysis materials containing single nutrients (or, in the case of ammonium phosphates, both nitrogen and phosphorus) are shipped in bulk form to retail bulk blending units. Here they are combined physically in mixtures suited to the particular needs of individual farmers. Thus, at no point in the distribution chain are the materials handled in any but bulk form.

With the availability of a wide variety of blends of the three nutrients at the retailing station, the demand for basic product shifted from the chemically mixed fertilizer materials to major blending materials such as ammonium nitrate, triple superphosphate, diammonium phosphate, and muriate of potash.

As this mode of distribution developed, many of the major manufacturers developed their own organization of bulk blending stations, thus emerging as the direct seller to the farmer. A typical large fertilizer organization might develop a chain of 100 to 200 such bulk blending stations. These would typically handle from 1000 to 5000 tons of material per year and generally sell within a radius of 15 miles.

Advantages of bulk blending can be summarized in the following: (1) bulk blending shortens the marketing channel by combining the mixer and dealer functions; (2) handling and distribution costs are less for bulk material than for bagged product; (3) bulk blending reduces handling costs by eliminating the transfer from producer to dealer; (4) shipping distance of materials such as potash is shortened because the material goes directly from primarily producer to the mixer-dealer rather than detouring to a granulation plant; (5) a custom application service can be offered; and (6) the bulk blender, through his close contact with the farmer, can work with agricultural advisors in guiding the[1] farmer's use of fertilizer. Assistance with soil testing and sampling is an important part of such a service.

Although this system is conceivable only as part of highly sophisticated national fertilizer supply and application chain and only countries with fairly developed agriculture can adopt it, it has its bearing on developing countries, too. The network initially developed in early stages of fertilizer production and distribution, composed of mini-plants and local dealers storage facilities can be easily transformed without any major change or investment. Local stores can be provided with bulk blending facilities with very little cost and the new, or expanded phosphate fertilizer production units can produce granulated products, while the nitrogen is already manufactured in granulated form. The use of drum or pan granulation in the early mini-plants is advantageous, the particle size is particularly suitable for bulk blending.

3.4.3 Bagging

Although as .much as possible of fertilizer output is dispatched as bulk, sometimes provision must be made for a significant amount of bagged product as well. Since bagging is a process with extremely high labour requirements, a fully automated line has been developed for this purpose.

Another question much debated is whether to use valved or cushion type bags. The latter are less expensive, prevent spillout, and protect the material much better: but weld sealing is difficult because of the fertilizer dust. The valve bags are more expensive and are not airtight, but they require no welding. Either type is available, according to the local conditions.

As compared to bulk goods, the handling of bagged fertilizers are much more labour-consuming operations.

Bagging in the mini-plant size range should be definitely discouraged for phosphates and limited even for nitrogen fertilizers. Anyhow, bulk storage and direct shipping to the plot is one of the most attractive features of mini-plants for the agriculture.

3.5 Potash Fertilizers

Potash, a major plant nutrient, is found in significant commercial deposits, as well as in less quantities in various brine operations. The principal potash mineral being mined is murate of potash (potassium chloride), and sulphate of potash. Both can be used as mined (after some refining) directly as fertilizer materials.

A minor amount of the potash, perhaps 10 %, is used for various non-fertilizer uses, such as in the production of potassium hydroxide, refined potassium salts, and other miscellaneous potassium chemicals. Fertilizer potash is used either directly as a fertilizer or as a raw material for the production of mixed fertilizers.

The principal potassium compound is the potassium chloride which is produced from natural brines and from sylvite ores. In the former case there are no hazardous wastes for disposal since the spent brine is returned to the well, which constitutes recycle. In the sylvite process, the ore is mined, crushed, screened, and wet-ground in brine to dissolve most of the soluble salts.

In the sylvite ore-based process the ore is separated from clay impurities in a desliming process and the clay impurities are fed to a gravity separator which removes some of the sodium chloride precipitated from the leach brine and insolubles for disposal as waste.

After desliming, the ore is chemically treated in preparation for a flotation process, where potassium chloride is separated from sodium chloride. The tailings from the flotation step are wasted and the resulting potassium chloride slurries are centrifuged to recover potassium chloride. The product is then dried, screened and packaged. The liquors from the centrifuge are recycled to the flotation circuit.

The potassium sulphate is produced by the reaction in solution of potassium chloride with langbeinite ore ($K_2SO_4 . MgSO_4$). Mined langbeinite is crushed and dissolved in water to which potassium chloride is added. Partial evaporation of the solution results in selective precipitation of potassium sulphate which is recovered by centrifugation or filtration, dried, and sold.

Generally this material is produced close to areas where it is mined.

4. IDENTIFICATION OF POTENTIAL MARKETS FOR MINI-FERTILIZER PLANTS

The world's ability to supply food depends on the following main factors:

- availability and use of natural resources including land
- weather
- water condition in the soil
- technological and biological development for raising yields
- equilibrium between crop and livestock production accomplished with increasing efficiency
- incentive to producers.

Although the world as a whole is clearly not running out of land, there are serious problems about its availability and suitability for agriculture, especially among some of the developing countries. The major problem facing many of the developing countries is not the limitation of land, but the low yields. Therefore, yield increasing technologies are to be the primary source of growth in food production.

Fertilizer use is one of the key factors in yield increases. To supply the ever increasing need of fertilizer in the developing countries, there are three means available: domestic production, importation, and combination of the two in any ratio. The domestic production can be done by setting fertilizer plants up. Taking into consideration the special circumstances in many developing countries, it can be stated that one or more mini-fertilizer plants of certain types and dimensions will better meet the requirements of those countries than one or more so called maxi-plants.

In order to be able to estimate the demand for mini-fertilizer plants, it is necessary to investigate the potential market for mini-plants.

Investigation and evaluation of the potential fertilizer markets by countries and regions were made in this chapter, surveying:

- the quantity of fertilizer consumed at present
- the forecast of the potential fertilizer consumption up to 2000
- raw materials' potential (resources)
- numbers and capacity of mini-fertilizer plants that might be built to the turn of the century in the developing countries.

The main sources for preparing this chapter were:

1. „Opportunities for establishment of mini-fertilizer plants in the developing countries" Sectoral Working Paper Series, Sectoral Studies Branch, Division for Industrial Studies, UNIDO 1983.
2. Data collected from FAO statistics:
   - "Agriculture toward 2000"
     Input Requirements: production, consumption, export, import figures from 1970/71 to 81/82 by nutrients and by type of fertilizers
   - Fertilizer Yearbook 1981
   - Data of land use by countries.
3. Other sources reported in each case.

4.1 Identification of countries according to the quantity of fertilizer consumed

The intensive use of fertilizers as a mean to increase agricultural production has become a general practice in the world, first of all in the developed countries. As for the developing countries, their consumption of the three nutrients was about 1 million tons in 1950, amounting to 7.4 per cent of the world consumption. Their share has reached the fifth of the whole world by the fertilizer year 1971/1972 and in 1981/1982 the developing countries required more than 38 million tons fertilizer nutrients, amounting to one third of the world consumption (Table 4.1-1).

Table 4.1-1

World fertilizer consumption

/million tons of nutrients/

Year	Developing countries					Developed countries					World total			
	N	P_2O_5	K_2O	Σ NPK	Share %	N	P_2O_5	K_2O	Σ NPK	Share %	N	P_2O_5	K_2O	Σ NPK
1950	0,56	0,36	0,09	1,01	7,4	3,19	5,41	4,04	12,64	92,6	3,75	5,77	4,13	13,65
1971/72	9,29	3,97	1,50	14,76	20,2	24,09	18,33	15,79	58,21	79,8	33,38	22,30	17,29	72,97
1976/77	13,86	6,27	2,43	22,56	23,6	31,32	21,21	20,51	73,04	76,4	45,18	27,48	22,94	95,60
1981/82	25,08	9,22	3,83	38,13	33,1	35,36	21,69	20,1	77,15	66,9	60,44	30,91	23,93	115,28

Sources: FAO Statistics collected from FAO Statistics Division;

Market Study of Mini-Fertilizer Plants for Developing Countries prepared

for UNIDO by Shu Lin Peng September 1982

Using FAO Statistics, the developing countries, about 123 in numbers, were classified into consumption categories, according to their annual consumption of Nitrogenous (N), Phosphate (P_2O_5) and Potassium (K_2O) fertilizer in 1976/77 and 1981/82. Seven classes were made for N and six for P_2O_5 and K_2O:

Category	Consumption (tons of nutrient)
I.	less than 1000
II.	1000 - 10000
III.	10000 - 40000
IV.	40000 - 70000
V.	70000 - 100000
VI.	100000 - 200000 (for N) over 100000 (for P_2O_5 and K_2O)
VII.	over 200000 (for N only)

As for the data of types of fertilizers, beside the total consumption in nutrients, the main types of N and P_2O_5 fertilizers can be found for some countries that publish them into FAO statistics.

The countries were arranged in groups by regions. Although, all the consumption data are available in 1976/77 and 1981/82 for 123 of developing countries in Appendix 4/1, the number of countries was reduced to 91 in the further considerations. They are the developing countries that were examined in "Agriculture toward 2000" by FAO, and China.

The regions and the developing countries studied are the following:

AFRICA

North-West Africa:	Algeria, Morocco, Tunisia
West Africa:	Benin, Gambia, Ghana, Guinea, Ivory Coast, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo, Upper Volta

Central Africa: Angola, Cameroon, Central African Republic, Chad, Congo, Gabon, Zaire

East and Southern Africa: Burundi, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Somalia, Tanzania, Uganda, Zambia, Zimbabwe

LATIN AMERICA

Central America: Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama

Caribbean: Cuba, Dominican Republic, Haiti, Jamaica

South America: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Trinidad a. Tobago, Uruguay, Venezuela

NEAR EAST

N.E. Africa: Egypt, Libya, Sudan

N.E. Asia: Afghanistan, Cyprus, Iran, Iraq, Jordan, Lebanon, Saudi-Arabia, Syria, Turkey, Yemen AR, Yemen PDR

FAR EAST

South Asia: Bangladesh, India, Nepal, Pakistan, Sri Lanka

East and South-East Asia: Burma, China, Indonesia, Kampuchea DM, Korea DPR, Korea Republic, Laos, Malaysia, Philippines, Thailand, Viet Nam

In Tables 4.1.-2, 4.1-3 and 4.1-4 the developing countries summarized by regions concerning to the above list can be seen according to ·their consumption categories of N and P_2O_5 and K_2O, respectively. It can be stated that more than one third of the examined countries consumed less than 10000 tpy N and 60 per cent of them could not reach the level of 40000 tpy N that refers to a mini scale unit capacity (150 tpd) for ammonia. On the other side a large number of them consumed more than 100000 tpy N even 14 countries were over 200000 tpy N including China, India, Mexico of which consumptions rose above million tpy N.

As for the phosphate fertilizer, half of the countries were below a consumption level of 10.000 t P_2O_5 and at the same time 13 of them consumed more than 100000 tpy P_2O_5. It is clear that there is a strong degree of polarization in the consumption of nitrogen and phosphate fertilizers. This manifestation is, however, not evident in the consumption of potassic fertilizer.

In Table 4.1-5 the participation of the main regions in the consumption categories can be seen separately for the three main nutrients. Generally, the African countries can be found in the low-consumption categories, except for the case of phosphate consumption. In this case their participation are also important in the high-consumption categories due to some countries having large phosphate rock deposits and developed phosphate fertilizer industries.

In another classification including 92 developing countries (Appendix 4/2), although, the considered countries and the category-ranges do not correspond exactly with the ones above mentioned, the conclusions are the same. Here a forecast of classification for 1986/87 and the foreseeable changes in each category are made.

Table 4.1-2

Share of the developing countries, according to the consumption categories of N fertilizer, by regions

/1981/82/

Region	I.		II.		III.		IV.		V.		VI.		VII.		Total	
	X	%	X	%	X	%	X	%	X	%	X	%	X	%	X	%
1. AFRICA	7	19,0	16	43,2	9	24,3	2	5,4	2	5,4	1	2,7	-	-	37	100
North-West Africa	-	-	-	-	1	33,3	1	33,3	1	33,4	-	-	-	-	3	100
West Africa	2	14,3	9	64,3	2	14,3	-	-	1	7,1	-	-	-	-	14	100
Central Africa	2	28,6	4	57,1	1	14,3	-	-	-	-	-	-	-	-	7	100
East and Southern Africa	3	23,1	3	23,1	5	38,4	1	7,7	-	-	1	7,7	-	-	13	100
2. LATIN AMERICA	-	-	6	25,0	7	29,2	5	20,8	1	4,2	2	8,3	3	12,5	24	100
Central America	-	-	-	-	3	42,9	3	42,9	-	-	-	-	1	14,2	7	100
Caribbean	-	-	1	25,0	2	50,0	-	-	-	-	-	-	1	25,0	4	100
South America	-	-	5	38,4	2	15,4	2	15,4	1	7,7	2	15,4	1	7,7	13	100
3. NEAR EAST	-	-	3	21,4	4	28,6	2	14,3	2	14,3	-	-	3	21,4	14	100
N.E. Africa	-	-	-	-	1	33,3	-	-	1	33,3	-	-	1	33,4	3	100
N.E. Asia	-	-	3	27,3	3	27,3	2	18,2	1	9,0	-	-	2	18,2	11	100
4. FAR EAST	-	-	1	6,3	2	12,4	-	-	1	6,3	4	25,0	8	50,0	16	100
South Asia	-	-	-	-	1	20,0	-	-	1	20,0	-	-	3	60,0	5	100
East and South-East Asia	-	-	1	9,1	1	9,1	-	-	-	-	4	36,4	5	45,4	11	100
Total	7	7,7	26	28,5	22	24,2	9	9,9	6	6,6	7	7,7	14	15,4	91	100

Remarks: The 91 of developing countries that projection of consumption to 2000 have been made for are included

X - countries in number

Table 4.1-3

Share of the developing countries, according to the consumption categories of P_2O_5 fertilizer, by regions

/1981/82/

gion	I.		II.		III.		IV.		V.		VI.		Total	
	X	%	X	%	X	%	X	%	X	%	X	%	X	%
1. AF A	9	24,3	18	48,7	5	13,5	2	5,4	3	8,1	-	-	37	100
No -West Africa	-	-	-	-	-	-	1	33,3	2	66,7	-	-	3	100
We frica	2	14,3	10	71,5	1	7,1	-	-	1	7,1	-	-	14	100
Ce al Africa	3	42,9	4	57,1	-	-	-	-	-	-	-	-	8	100
Ea and Southern Africa	4	30,8	4	30,8	4	30,8	1	7,6	-	-	-	-	12	100
2. LA AMERICA	2	8,3	8	33,3	7	29,3	3	12,5	2	8,3	2	8,3	24	100
Ce al America	-	-	3	42,8	3	42,8	-	-	-	-	1	14,4	7	100
Ca bean	-	-	2	50,0	1	25,0	-	-	1	25,0	-	-	4	100
So America	2	15,6	3	23,0	3	23,0	3	23,0	1	7,7	1	7,7	13	100
3. NE EAST	3	21,4	3	21,4	3	21,4	2	14,4	-	-	3	21,4	14	100
N. Africa	1	33,3	-	-	-	-	1	33,3	-	-	1	33,4	3	100
N. Asia	2	18,2	3	27,3	3	27,3	1	9,0	-	-	2	18,2	11	100
4. F EAST	1	6,3	2	12,5	2	12,5	2	12,5	1	6,2	8	50,0	16	100
S Asia	-	-	1	20,0	1	20,0	-	-	-	-	3	60,0	5	100
E and South-East Asia	1	9,1	1	9,1	1	9,1	2	18,2	1	9,1	5	45,4	11	100
Tota	15	16,5	31	34,0	17	18,7	9	9,9	6	6,6	13	14,3	91	100

Rema : The 91 of developing countries that projection of consumption to 2000 have been made for are included.

X - countries in number

Table 4.1-4

Share of the developing countries, according to the consumption categories of K_2O fertilizer, by regions

/1981/82/

R e g i o n	I.		II.		III.		IV.		V.		VI.		Total	
	X	%	X	%	X	%	X	%	X	%	X	%	X	%
1. ICA	15	40,5	15	40,5	7	19,0	-	-	-	-	-	-	37	100
th-West Africa	-	-	1	33,3	2	66,7	-	-	-	-	-	-	3	100
t Africa	6	42,9	5	35,7	3	21,4	-	-	-	-	-	-	14	100
tral Africa	3	37,5	4	50,0	1	12,5	-	-	-	-	-	-	8	100
t and Southern Africa	6	50,0	5	41,7	1	8,3	-	-	-	-	-	-	12	100
2. IN AMERICA	2	8,3	8	33,4	10	41,7	2	8,3	-	-	2	8,3	24	100
tral America	-	-	1	14,3	5	71,4	1	14,3	-	-	-	-	7	100
ribbean	-	-	2	50,0	1	25,0	-	-	-	-	1	25,0	4	100
uth America	2	15,4	5	38,4	4	30,8	1	7,7	-	-	1	7,7	13	100
3. R EAST	5	35,7	6	42,9	3	21,4	-	-	-	-	-	-	14	100
E. Africa	1	33,3	1	33,3	1	33,4	-	-	-	-	-	-	3	100
E. Asia	4	36,4	5	45,4	2	18,2	-	-	-	-	-	-	11	100
4. R EAST	2	12,5	1	6,3	5	31,2	2	12,5	1	6,3	5	31,2	16	100
uth Asia	1	20,0	-	-	2	40,0	1	20,0	-	-	1	20,0	5	100
st and South-East Asia	1	9,1	1	9,1	3	27,2	1	9,1	1	9,1	4	36,4	11	100
T	24	26,4	30	32,9	25	27,5	4	4,4	1	1,1	7	7,7	91	100

R rks: The 91 of developing countries that projection of consumption to 2000 have been made for are included.

X - countries in number

Table 4.1-5

Regional distribution of consumption categories (1981/82) (%)

Category Region	I	II	III	IV	V	VI	VII
				Nitrogen			
1. Africa	100,0	61,5	40,9	22,2	33,3	14,3	----
2. Latin America	----	23,2	31,8	55,6	16,7	28,6	21,4
3. Near East	----	11,5	18,2	22,2	33,3	----	21,4
4. Far East	----	3,8	9,1	----	16,7	57,1	57,2
				Phosphate			
1. Africa	60,0	58,0	29,4	22,2	50,0	----	
2. Latin America	13,3	25,8	41,2	33,4	33,3	15,4	
3. Near East	20,0	9,7	17,6	22,2	----	23,1	
4. Far East	6,7	6,5	11,8	22,2	16,7	61,5	
				Potassic			
1. Africa	62,6	50,0	28,0	----	----	----	
2. Latin America	8,3	26,7	40,0	50,0	----	28,6	
3. Near East	20,8	20,0	12,0	----	----	----	
4. Far East	8,3	3,3	20,0	50,0	100,0	71,4	

4.2 Identification of countries according to their agricultural potential

Among the most prevalent ills affecting mankind are famine and malnutrition. The latter, although harder to define and overcome than the former, afflicts a very large proportion of population in developing countries.

The existence of malnutrition is usually explained by combination of three main factors in the developing countries: insufficient food, lack of some essential nutrients in the diet, genetic or environmental prevention of adequate food digestion.

The simplest food cycle is to grow plants and eat parts of them. However, as food consumption patterns differ widely from one region to the other, the farmers have adopted their food production systems accordingly. Farming systems are characterized by the dominant crops, that have emerged in each area as result of ecological, biological, economic and social factors in the society that grows the crops. The most important single objective in farming is to increase crop yield and agricultural productivity.

The factors that determine agricultural yield are complex for the photosynthetic potential of the plants. This potential is usually limited by elements such as nutrients, moisture and climate. The major source of plant nutrients is the mineral supply of the soil. This supply varies with the type of soil and ecological conditions in the area and accounts for large differences in fertility between temperate, tropical and arid soils.

Following farming, sooner or later the organic matter content of the soil will decrease to a level at which as much nutrient should be added as have removed by the biomasse. The use of fertilizers is a key factor for restoring and also increasing of fertility of the soil. However, fertilizers alone cannot produce substantial crop yield increases without highly efficient seeds, improved agricultural practices etc.

The forecast of fertilizer use, in this manner, is to be decided upon by considering numerous criterias like it has happened in the study "Agriculture toward 2000" made by FAO. The cornerstone of the production analyses in that study was the quantitative assessment of natural resources and input requirements. Based upon these, proposals were made on possibilities for resource development, land use patterns, yield increase, etc. Two alternative projections, Scenarios A and B, were made for 90 developing countries listed in the earlier chapter.

The main differences in the two scenario projections reflect the following factors:

- different economic growth rates
  - for Scenario A: the aggregate growth rate 7,0 per cent per year and the low income developing countries (300 Dollar GDP per capital or less in 1975) at least double their per capital incomes by 2000.
  - for Scenario B: the growth rate less optimistic, 5,7 per cent per year.
- different production projections
  - for Scenario A: commodity by commodity are for levels which imply maximum improvements in self-sufficiency or exports subject to constraints on the production side (land/water resources and gains in land use). For each crop, production increases are specified in terms of changes in yields and harvested area for six classes of irrigated and rainful land.
  - for Scenario B: a more mechanical procedure was followed; countries are assumed to achieve production growth rates commodity by commodity that are midway between those of past trends and those of Scenario A. The increases in total production thus obtained for "B" subsequently broken down into changes in area and yields proportionate to those of "A".

As for the manner of estimation of fertilizer requirements, it is the same in both alternatives. The projected fertilizer use, of course, will be different because the two scenarios have different levels of projected area, yields and production.

For our forecast of fertilizer use in the 91 developing countries up to 1990 and 2000, we considered the following data:

- The FAO estimations above mentioned; FAO placed all the input requirements including fertilizers at our disposal for each developing countries studied in the two Scenarios.
- Projection of fertilizer demand made by Mr. Shu Lin Peng in his "Market Study of Mini-Fertilizer Plants for Developing Countries", September 1982.
- The historical data of fertilizer use in each country.

Taking into consideration the information above mentioned, forecasts were made for the use of the three main nutrients in 1990 and 2000. Tables 4.2-1, 4.2-2 and 4.2-3 contain the forecasts of N, P_2O_5 and K_2O for each country, respectively. Data of FAO Scenario A and of Mr. Peng also are shown in the tables together with category-signs listed in the former chapter, based on our forecasts.

In Tables 4.2-4 to 4.2-9 the share of developing countries according to the consumption categories of N, P_2O_5 and K_2O fertilizers by regions are summarized, based on our forecasts for 1990 and 2000, respectively.

Comparing the recent share (Table 4.1-2) with the forecasts (Table 4.2-4 and 4.2-5) in case of nitrogen, it can be seen that even in 2000 a number of countries, 25 or expressed in percentage 27,5 per cent, will not reach the level of 10000 tpy N. On the other hand, the number of countries consuming more than 200000 tpy will increase from 14 in 1981/82 to 26 in 2000, presenting a further, even more polarization in the consumption of the developing countries.

The main ranges in nitrogen consumption in 2000 would be the category VII. (consumption above 200000 tpy N) with 28,6 per cent and the consumption level 1000-10000 tpy N with 24,2 per cent.

Similar changes can be seen on the base of data available in Tables 4.1-3, 4.2-6 and 4.2-7 in case of P_2O_5 consumption and in Tables 4.1-4, 4.2-8 and 4.2-9 in case of K_2O consumption. There will be a difference in case of K_2O consumption because the main ranges would be the consumption levels from 1000 to 10000 and from 10000 to 40000 amounting to about 32 per cent and 27,5 per cent, respectively. This is corresponding to the forecast philosophy that in this period the developing countries will not reach the N:P:K ratio that has evolved in the developed economies.

Table 4.2-1

Forecasts of N fertilizer consumption toward 2000 in the developing countries and classification into categories

1000 t N

Country	1990				2000			
	Estimates			Cat.[d]	Estimates			Cat.[d]
	FAO[a]	UNIDO			FAO[a]	UNIDO		
		b	c			b	c	
1. AFRICA			932,7				1900,4	
North-West Africa			290,0				656,0	
Algeria	135,0	132,0	120,0	VI.	450,0	266,0	266,0	VII.
Morocco	135,0	204,0	120,0	VI.	320,0	410,0	260,0	VII.
Tunisia	40,0	58,0	50,0	IV.	186,0	116,0	130,0	VI.
West Africa			198,2				434,3	
Benin	3,2	-	2,5	II.	6,2	-	4,7	II.
Gambia	0,1	-	2,0	II.	1,3	-	3,0	II.
Ghana	9,0	16,0	15,0	III.	48,1	32,0	34,0	III.
Guinea	1,2	-	0,9	I.	4,1	-	3,3	II.
Ivory Coast	30,6	25,7	25,0	III.	115,4	51,4	80,0	V.
Liberia	0,8	4,7	2,5	II.	3,3	9,4	3,3	II.
Mali	5,5	-	9,0	II.	18,5	-	15,0	III.
Mauritania	0,6	-	2,0	II.	5,7	-	4,0	II.
Niger	0,5	-	1,7	II.	1,8	-	2,5	II.
Nigeria	32,6	122,0	120,0	VI.	101,9	244,0	210,0	VII.
Senegal	13,0	15,8	11,0	III.	87,1	31,5	60,0	IV.
Sierra Leone	3,3	3,1	2,6	II.	26,1	6,0	8,4	II.
Togo	1,1	-	2,0	II.	4,3	-	3,5	II.
Upper Volta	1,1	-	2,0	II.	3,2	-	2,6	II.
Central Africa			52,4				89,1	
Angola	3,9	20,1	12,3	III.	16,3	40,0	25,0	III.
Cameroon	9,6	24,0	28,0	III.	38,3	48,0	39,0	III.
Centr. Afr. Rep.	1,6	-	1,3	II.	4,0	-	2,8	II.
Chad	5,3	-	3,6	II.	18,8	-	8,8	II.

Table 4.2-1 /cont'd/

1000 t N

Country	1990				2000			
	Estimates			Cat.[d]	Estimates			Cat.[d]
	FAO[a]	UNIDO			FAO[a]	UNIDO		
		b	c			b	c	
Congo	4,7	-	3,2	II.	14,7	-	7,0	II.
Gabon	0,3	-	0,3	I.	0,5	-	0,5	I.
Zaire	2,8	-	3,7	II.	5,8	-	6,0	II.
East and Southern Africa			392,1				721,0	
Burundi	1,1	-	0,9	I.	2,9	-	2,3	II.
Ethiopia	20,1	56,7	35,0	III.	80,5	113,0	64,0	IV.
Kenya	56,8	40,8	41,0	IV.	172,0	81,6	120,0	VI.
Madagascar	5,9	7,5	5,9	II.	22,1	15,0	15,0	III.
Malawi	12,8	30,0	28,3	III.	40,3	60,0	40,3	IV.
Mauritius	21,4	19,2	17,0	III.	25,7	30,0	25,7	III.
Mozambique	7,1	22,8	22,8	III.	10,8	45,6	35,0	III.
Rwanda	0,3	-	0,3	I.	0,8	-	0,7	I.
Somalia	4,2	-	3,4	II.	13,8	-	11,0	III.
Tanzania	35,9	47,0	33,0	III.	110,3	94,0	88,0	V.
Uganda	2,4	-	2,0	II.	10,3	-	7,0	II.
Zambia	40,9	87,0	72,5	V.	139,3	174,0	128,0	VI.
Zimbabwe	99,7	88,8	130,0	VI.	229,8	133,0	184,0	VI.
2. LATIN AMERICA			4205,8				7209,2	
Central America			1651,0				2380,0	
Costa Rica	65,4	66,6	58,5	IV.	123,5	106,6	104,0	VI.
El Salvador	98,7	84,0	79,0	V.	176,3	134,4	132,0	VI.
Guatemala	63,6	94,2	62,5	IV.	118,1	151,0	105,0	VI.
Honduras	31,4	16,6	22,0	III.	75,0	26,6	52,0	IV.
Mexico	926,5	1366,0	1366,0	VII.	1752,6	2186,0	1890,0	VII.
Nicaragua	29,7	42,0	42,0	IV.	51,9	67,2	52,0	IV.
Panama	30,5	19,5	21,0	III.	64,8	31,0	45,0	IV.

Table 4.2-1 /cont'd/

1000 t N

Country	1990				2000			
	Estimates			Cat.[d]	Estimates			Cat.[d]
	FAO[a]	UNIDO			FAO[a]	UNIDO		
		b	c			b	c	
Caribbean			462,6				687,7	
Cuba	240,5	480,0	392,0	VII.	383,9	768,0	581,0	VII.
Dominican Rep.	71,8	57,0	57,0	IV.	101,0	91,0	85,0	V.
Haiti	1,6	-	1,6	II.	4,6	-	3,7	II.
Jamaica	12,0	-	12,0	III.	22,2	-	18,0	III.
South America			2092,2				4141,5	
Argentina	82,7	95,3	75,0	V.	141,0	152,0	120,0	VI.
Bolivia	3,9	3,7	3,5	II.	9,0	7,4	7,4	II.
Brazil	1820,0	1300,0	1300,0	VII.	4063,0	2080,0	2844,0	VII.
Chile	175,0	88,0	99,0	V.	347,6	140,0	162,0	VI.
Colombia	223,1	280,0	195,0	VI.	372,9	448,0	300,0	VII.
Ecuador	37,7	74,4	66,5	IV.	120,0	120,0	120,0	VI.
Guyana	9,1	-	12,5	III.	13,2	-	16,5	III.
Paraguay	3,5	2,5	2,9	II.	5,6	4,9	4,9	II.
Peru	69,7	147,0	147,0	VI.	176,2	226,7	226,0	VII.
Suriname	4,0	-	5,8	II.	6,7	-	6,7	II.
Trinidad a.Tobago	6,1	-	5,0	II.	10,0	-	8,0	II.
Uruguay	22,4	32,0	32,0	III.	94,0	41,6	46,0	IV.
Venezuela	185,4	189,0	148,0	VI.	311,1	300,0	280,0	VII.
3. NEAR EAST			2830,2				4238,4	
N.E. Africa			945,0				1369,0	
Egypt	384,2	823,0	823,0	VII.	566,6	1316,0	1120,0	VII.
Libya	20,0	41,0	41,0	IV.	45,8	82,0	69,0	IV.
Sudan	80,9	-	81,0	V.	239,7	-	180,0	VI.

Table 4.2-1 /cont'd/

1000 t N

Country	1990				2000			
	Estimates			Cat.[d]	Estimates			Cat.[d]
	FAO[a]	UNIDO			FAO[a]	UNIDO		
		b	c			b	c	
N.E. Asia			1885,2				2869,4	
Afghanistan	20,5	-	36,0	III.	118,6	-	83,0	V.
Cyprus	14,5	-	12,0	III.	26,2	-	21,0	III.
Iran	481,5	493,0	490,0	VII.	1405,2	789,0	800,0	VII.
Iraq	57,3	155,0	135,0	VI.	314,7	310,0	263,0	VII.
Jordan	5,3	9,2	5,0	II.	7,8	18,1	8,5	II.
Lebanon	24,1	35,0	27,0	III.	50,3	70,0	48,0	IV.
Saudi-Arabia	6,5	26,0	44,0	IV.	51,5	52,0	52,0	IV.
Syria	67,8	150,0	110,0	VI.	98,8	300,0	170,0	VI.
Turkey	917,4	1262,0	1010,0	VII.	1347,7	2021,0	1400,0	VII.
Yemen AR	1,3	-	14,0	III.	8,4	-	21,0	III.
Yemen PDR	0,7	-	2,2	II.	2,4	-	2,9	II.
4. FAR EAST			26039,2				41416,4	
South Asia			7577,0				15330,0	
Bangladesh	418,2	508,8	420,0	VII.	960,9	1018,0	910,0	VII.
India	6897,0	5666,0	5660,0	VII.	16791,6	9066,0	11750,0	VII.
Nepal	20,4	-	22,0	III.	58,0	-	46,0	IV.
Pakistan	2550,9	1340,0	1340,0	VII.	5754,3	2144,0	2400,0	VII.
Sri Lanka	158,7	143,0	135,0	VI.	279,7	229,0	224,0	VII.
East and South-East Asia			18462,2				26086,4	
Burma	142,9	148,0	143,0	VI.	280,3	237,0	237,0	VII.
China	...	14231,0	14231,0	VII.	...	19923,0	19923,0	VII.
Indonesia	911,0	1300,0	1370,0	VII.	1079,0	2600,0	2100,0	VII.
Kampuchea DM	1,6	-	11,0	III.	4,3	-	15,0	III.
Korea DPR	336,8	775,6	776,0	VII.	379,1	1086,0	850,0	VII.
Korea Rep.	748,9	721,0	721,0	VII.	815,3	1154,0	815,0	VII.
Laos	0,1	-	0,2	I.	0,5	-	0,4	I.

Table 4.2-1 /cont'd/

1000 t N

Country	1990				2000			
	Estimates			Cat.[d]	Estimates			Cat.[d]
	FAO[a]	UNIDO			FAO[a]	UNIDO		
		b	c			b	c	
Malaysia	65,4	290,0	230,0	VII.	243,9	464,0	346,0	VII.
Philippines	288,1	384,0	350,0	VII.	774,3	610,0	600,0	VII.
Thailand	313,3	346,0	250,0	VII.	579,5	690,0	480,0	VII.
Viet Nam	568,9	-	380,0	VII.	1376,0	-	720,0	VII.
TOTAL			34007,9				54764,4	

Remarks:

a - "Agriculture toward 2000" FAO, Scenario "A" - Potential Demand Forecast.

b - Market study of mini-fertilizer plants for developing countries by Shu Lin Peng Ph.D. for UNIDO, September 1982.

c - Demand forecast specially prepared by the Hungarian Chemical Industries Engineering Center /VEGYTERV/, Budapest, for this study.

d - Consumption categories:

Category	Consumption /tpy N/
I.	less than 1000
II.	1000 - 10000
III.	10000 - 40000
IV.	40000 - 70000
V.	70000 - 100000
VI.	100000 - 200000
VII.	over 200000

Table 4.2 -2

Forecasts of P_2O_5 fertilizer consumption toward 2000 in the developing countries and classification into categories

1000 t $P2O_5$

Country	1990				2000			
	Estimates			Cat.^{d}	Estimates			Cat.^{d}
	FAO^a	UNIDO			FAO^a	UNIDO		
		b	c			b	c	
1. AFRICA			713,3				1527,7	
North-West Africa			307,0				714,0	
Algeria	147,4	165,0	125,0	VI.	552,4	333,0	270,0	VI.
Morocco	180,6	159,0	120,0	VI.	418,3	320,0	290,0	VI.
Tunisia	44,7	61,7	62,0	IV.	220,0	123,0	154,0	VI.
West Africa			161,1				301,9	
Benin	2,7	-	2,2	II.	4,7	-	3,8	II.
Gambia	0,1	-	1,8	II.	1,1	-	2,8	II.
Ghana	8,1	11,5	10,5	III.	38,6	23,0	23,0	III.
Guinea	1,0	-	1,1	II.	2,9	-	2,3	II.
Ivory Coast	21,4	12,3	15,0	III.	70,0	24,6	49,0	IV.
Liberia	0,4	2,3	1,9	II.	2,3	4,7	2,3	II.
Mali	4,2	-	5,3	II.	15,4	-	10,2	III.
Mauritania	0,4	-	1,2	II.	3,8	-	2,2	II.
Niger	0,4	-	1,8	II.	1,6	-	2,3	II.
Nigeria	24,6	70,0	90,0	V.	81,3	139,0	140,0	VI.
Senegal	10,8	27,0	24,0	III.	78,7	54,0	54,0	IV.
Sierra Leone	3,2	2,3	2,2	II.	17,7	4,6	4,6	II.
Togo	1,0	-	1,8	II.	3,4	-	2,7	II.
Upper Volta	0,9	-	2,3	II.	2,5	-	2,7	II.
Central Africa			27,4				52,1	
Angola	3,5	4,3	7,2	II.	14,2	8,6	11,0	III.
Cameroon	8,0	11,3	11,3	III.	31,2	22,9	21,0	III.
Centr. Afr. Rep.	1,7	-	1,1	II.	4,4	-	2,3	II.

-

Table 4.2-2 /cont'd/

1000 t P_2O_5

Country	1990				2000			
	Estimates			Cat.^{d}	Estimates			Cat.^{d}
	FAO^a	UNIDO			FAO^a	UNIDO		
		b	c			b	c	
Chad	5,0	-	2,7	II.	13,5	-	6,8	II.
Congo	4,3	-	2,1	II.	15,7	-	6,2	II.
Gabon	0,2	-	0,2	I.	0,3	-	0,3	I.
Zaire	2,9	-	2,8	II.	5,6	-	4,5	II.
East and Southern Africa			**217,8**				**459,7**	
Burundi	1,1	-	0,9	I.	2,9	-	2,3	II.
Ethiopia	20,1	107,2	38,0	III.	93,3	214,0	71,0	V.
Kenya	41,5	36,0	36,0	III.	129,1	72,0	90,0	V.
Madagascar	4,4	1,9	3,0	II.	15,2	3,7	11,0	III.
Malawi	9,3	9,0	9,0	II.	35,3	18,0	25,0	III.
Mauritius	14,3	4,0	7,0	II.	17,4	9,6	12,0	III.
Mozambique	4,1	6,3	15,0	III.	14,4	12,4	21,0	III.
Rwanda	0,5	-	0,3	I.	1,2	-	0,7	I.
Somalia	3,1	-	2,4	II.	10,1	-	8,0	II.
Tanzania	26,0	10,8	18,0	III.	78,8	21,6	39,0	III.
Uganda	1,9	-	1,2	II.	8,0	-	3,7	II.
Zambia	31,2	30,6	30,0	III.	119,5	61,0	61,0	IV.
Zimbabwe	73,8	57,4	57,0	IV.	164,3	86,0	115,0	VI.
2. LATIN AMERICA			**2996,4**				**5199,5**	
Central America			**696,0**				**1284,0**	
Costa Rica	47,2	21,6	27,0	III.	89,3	34,6	48,0	IV.
El Salvador	67,6	30,0	42,0	IV.	123,7	48,0	75,0	V.
Guatemala	42,2	45,4	42,0	IV.	80,3	72,6	71,0	V.
Honduras	25,4	5,2	12,0	III.	62,1	8,3	28,0	III.
Mexico	772,1	425,0	540,0	VI.	1437,7	680,0	1006,0	VI.
Nicaragua	19,7	25,4	18,0	III.	37,6	40,7	30,0	III.
Panama	21,2	10,9	15,0	III.	45,2	17,0	26,0	III.

Table 4.2-2 /cont'd/

1000 t P_2O_5

Country	1990				2000			
	Estimates			Cat.[d]	Estimates			Cat.[d]
	FAO[a]	UNIDO			FAO[a]	UNIDO		
		b	c			b	c	
Caribbean			164,8				259,7	
Cuba	168,0	115,0	118,0	VI.	253,9	183,0	190,0	VI.
Dominican Rep.	53,8	29,0	38,0	III.	75,6	46,0	53,0	IV.
Haiti	1,4	-	1,4	II.	4,0	-	2,7	II.
Jamaica	9,3	-	7,4	II.	17,3	-	14,0	III.
South America			2135,6				3655,8	
Argentina	75,6	95,3	66,0	IV.	133,4	152,0	107,0	VI.
Bolivia	3,1	4,9	3,5	II.	7,3	10,0	6,0	II.
Brazil	1585,7	2750,0	1600,0	VI.	3427,3	4400,0	2740,0	VI.
Chile	191,3	115,0	115,0	VI.	391,8	184,0	188,0	VI.
Colombia	139,2	135,4	120,0	VI.	240,2	217,0	192,0	VI.
Ecuador	26,1	52,0	26,0	III.	84,9	83,0	68,0	IV.
Guyana	6,2	-	5,0	II.	8,8	-	7,0	II.
Paraguay	3,2	1,8	4,9	II.	5,0	3,7	5,0	II.
Peru	49,3	25,5	35,0	III.	123,0	40,8	69,0	IV.
Suriname	1,7	-	1,4	II.	3,5	-	2,8	II.
Trinidad and Tobago	4,7	-	3,8	II.	7,4	-	6,0	II.
Uruguay	18,0	95,5	50,0	IV.	93,0	124,0	93,0	V.
Venezuela	125,8	138,0	105,0	VI.	214,4	220,0	172,0	VI.
3. NEAR EAST			1527,8				2589,8	
N.E. Africa			258,0				463,0	
Egypt	308,7	162,0	195,0	VI.	455,0	260,0	320,0	VI.
Libya	21,6	66,0	58,0	IV.	52,8	132,0	93,0	V.
Sudan	62,3	-	5,0	II.	204,2	-	50,0	II.

Table 4.2-2 /cont'd/

1000 t P_2O_5

Country	1990				2000			
	Estimates			Cat.[d]	Estimates			Cat.[d]
	FAO[a]	UNIDO			FAO[a]	UNIDO		
		b	c			b	c	
N.E. Asia			1269,8				2126,8	
Afghanistan	19,4	-	16,0	III.	91,1	-	37,0	III.
Cyprus	11,0	19,7	9,0	II.	20,6	31,5	17,0	III.
Iran	454,2	316,0	318,0	VI.	1398,8	506,0	570,0	VI.
Iraq	46,7	52,6	41,0	IV.	281,9	105,0	105,0	VI.
Jordan	4,9	9,2	4,9	II.	7,9	18,4	8,0	II.
Lebanon	22,0	50,4	22,0	III.	48,7	100,8	41,0	IV.
Saudi-Arabia	6,6	9,7	24,0	III.	37,8	19,4	38,0	III.
Syria	63,0	88,8	60,0	IV.	90,3	177,6	85,0	V.
Turkey	965,9	1103,0	773,0	VI.	1520,6	1745,0	1217,0	VI.
Yemen AR	1,8	-	1,4	II.	9,1	-	7,3	II.
Yemen PDR	0,6	-	0,5	I.	1,9	-	1,5	II.
4. FAR EAST			8215,7				13987,1	
South Asia			2825,0				5342,0	
Bangladesh	222,5	237,4	185,0	VI.	493,6	475,0	395,0	VI.
India	5241,3	1666,0	2180,0	VI.	12326,6	2666,0	4110,0	VI.
Nepal	9,8	-	8,0	II.	29,0	-	23,0	III.
Pakistan	2256,6	389,6	400,0	VI.	5070,6	623,4	720,0	VI.
Sri Lanka	74,8	59,0	52,0	IV.	134,2	94,0	94,0	V.
East and South-East Asia			5390,7				8645,1	
Burma	71,0	63,4	57,0	IV.	147,5	101,0	110,0	VI.
China	-	3812,0	3812,0	VI.	-	6100,0	6100,0	VI.
Indonesia	456,0	310,0	410,0	VI.	579,8	620,0	580,0	VI.
Kampuchea DM	0,8	-	0,6	I.	2,3	-	1,8	II.
Korea DPR	207,1	193,3	190,0	VI.	253,3	257,0	250,0	VI.
Korea Rep.	410,3	354,4	295,0	VI.	493,1	567,0	395,0	VI.
Laos	0,1	-	0,1	I.	0,4	-	0,3	I.

Table 4.2-2 /cont'd/

1000 t P_2O_5

Country	1990				2000			
	Estimates			Cat.^{d}	Estimates			Cat.^{d}
	FAO^a	UNIDO			FAO^a	UNIDO		
		b	c			b	c	
Malaysia	30,5	208,0	160,0	VI.	102,7	333,0	234,0	VI.
Philippines	196,8	84,0	84,0	V.	514,6	134,0	180,0	VI.
Thailand	201,2	257,0	182,0	VI.	366,9	514,0	310,0	VI.
Viet Nam	251,4	-	200,0	VI.	604,9	-	484,0	VI.
TOTAL			13453,2				23304,1	

Remarks:

a - "Agriculture toward 2000" FAO, Scenario "A" - Potential Demand Forecast.

b - Market study of mini-fertilizer plants for developing countries by Shu Lin Peng Ph.D. for UNIDO, September 1982.

c - Demand forecast specially prepared by the Hungarian Chemical Industries Engineering Center /VEGYTERV/, Budapest, for this study.

d - Consumption categories:

Category	Consumption /tpy N/
I.	less than 1000
II.	1000 - 10000
III.	10000 - 40000
IV.	40000 - 70000
V.	70000 - 100000
VI.	over 100000

Table 4.2-3

Forecasts of K_2O fertilizer consumption toward 2000 in the developing countries and classification into categories

1000 t K_2O

Country	1990				2000			
	Estimates			Cat.^{d}	Estimates			Cat.^{d}
	FAO^a	UNIDO			FAO^a	UNIDO		
		b	c			b	c	
1. AFRICA			361,0				786,5	
North-West Africa			125,6				307,0	
Algeria	54,8	55,0	55,0	IV.	1868,0	111,0	130,0	VI.
Morocco	46,3	89,0	60,0	IV.	109,0	180,0	135,0	VI.
Tunisia	15,2	8,0	10,6	III.	77,1	16,0	42,0	IV.
West Africa			105,0				203,4	
Benin	2,8	-	2,0	II.	6,0	-	2,7	II.
Gambia	-	-	0,5	I.	0,5	-	0,5	I.
Ghana	8,0	9,2	7,2	II.	27,7	18,0	19,0	III.
Guinea	1,0	-	1,1	II.	2,5	-	2,0	II.
Ivory Coast	39,5	34,8	35,0	III.	157,2	73,6	89,0	V.
Liberia	3,8	2,3	1,9	II.	8,5	4,7	2,3	II.
Mali	1,5	-	4,5	II.	6,6	-	6,6	II.
Mauritania	0,2	-	0,4	I.	1,7	-	1,4	II.
Niger	0,1	-	0,4	I.	0,5	-	0,5	I.
Nigeria	15,8	35,0	35,0	III.	40,9	67,0	41,0	IV.
Senegal	5,9	15,8	13,0	III.	38,7	31,5	31,0	III.
Sierra Leone	2,0	0,8	1,4	II.	5,3	1,5	3,7	II.
Togo	0,7	-	1,2	II.	2,7	-	2,0	II.
Upper Volta	0,3	-	1,4	II.	0,8	-	1,7	II.
Central Africa			30,8				62,5	
Angola	2,5	4,3	4,2	II.	13,1	8,6	9,0	II.
Cameroon	18,6	22,7	19,0	III.	47,8	45,4	38,0	III.
Centr. Afr. Rep.	0,9	-	0,7	I.	2,3	-	1,4	II.
Chad	2,2	-	1,8	II.	5,6	-	4,5	II.

Table 4.2-3 /cont'd/

1000 t K_2O

Country	1990				2000			
	Estimates			Cat.[d]	Estimates			Cat.[d]
	FAO[a]	UNIDO			FAO[a]	UNIDO		
		b	c			b	c	
Congo	2,7	-	2,2	II.	8,0	-	6,0	II.
Gabon	0,2	-	0,3	I.	0,5	-	0,4	I.
Zaire	1,9	-	2,6	II.	3,4	-	3,2	II.
East and Southern Africa			99,6				213,6	
Burundi	0,4	-	0,4	I.	1,0	-	0,9	I.
Ethiopia	5,9	-	4,7	II.	18,1	-	14,5	III.
Kenya	10,7	15,9	10,7	III.	35,0	31,8	32,0	III.
Madagascar	2,5	7,5	2,5	II.	7,9	15,0	7,9	II.
Malawi	4,8	7,0	4,5	II.	14,0	14,0	14,0	III.
Mauritius	9,4	29,5	14,0	III.	11,4	47,0	18,0	III.
Mozambique	2,7	8,4	3,5	II.	11,8	16,8	9,5	II.
Rwanda	0,1	-	0,1	I.	0,2	-	0,2	I.
Somalia	1,4	-	1,1	II.	4,5	-	3,6	II.
Tanzania	12,2	3,6	8,5	II.	45,6	7,2	26,0	III.
Uganda	1,0	-	0,8	I.	3,6	-	3,0	II.
Zambia	13,0	8,2	9,0	II.	60,9	16,0	20,0	III.
Zimbabwe	20,8	42,8	39,8	III.	40,7	64,0	64,0	IV.
2. LATIN AMERICA			1935,1				3479,0	
Central America			259,5				518,3	
Costa Rica	40,9	45,8	33,0	III.	70,5	73,3	56,0	IV.
El Salvador	27,3	10,0	16,8	III.	55,0	16,0	31,0	III.
Guatemala	19,3	33,0	24,0	III.	36,7	52,8	30,0	III.
Honduras	18,2	9,8	12,7	III.	40,9	15,7	22,8	III.
Mexico	358,9	101,0	145,0	VI.	677,4	162,0	335,0	VI.
Nicaragua	7,9	20,5	15,0	III.	14,1	23,8	21,5	III.
Panama	14,3	18,3	13,0	III.	27,9	29,0	22,0	III.

Table 4.2-3 /cont'd/

1000 t K_2O.

Country	1990				2000			
	Estimates			Cat.[d]	Estimates			Cat.[d]
	FAO[a]	UNIDO			FAO[a]	UNIDO		
		b	c			b	c	
Caribbean			225,2				327,6	
Cuba	100,3	356,0	195,0	VI.	142,9	410,0	285,0	VI.
Dominican Rep.	28,5	33,0	23,0	III.	40,0	53,0	32,0	III.
Haiti	0,6	-	1,1	II.	1,3	-	1,3	II.
Jamaica	5,4	-	6,1	II.	10,8	-	9,3	II.
South America			1450,4				2633,1	
Argentina	17,6	17,3	14,0	III.	30,0	28,0	24,0	III.
Bolivia	1,5	1,2	1,2	II.	4,5	2,4	3,0	II.
Brazil	421,6	1780,0	1230,0	VI.	991,2	2850,0	2192,0	VI.
Chile	67,1	21,7	21,7	III.	137,2	34,7	96,0	V.
Colombia	65,3	130,4	75,0	V.	115,1	209,0	115,0	VI.
Ecuador	16,8	34,6	22,0	III.	60,4	55,4	48,0	IV.
Guyana	3,6	-	3,0	II.	5,2	-	4,2	II.
Paraguay	0,8	3,1	2,1	II.	1,4	6,1	3,1	II.
Peru	22,5	14,2	16,0	III.	58,2	22,7	39,0	III.
Suriname	1,7	-	0,8	I.	3,8	-	1,6	II.
Trinidad a.Tobago	2,2	-	3,2	II.	4,2	-	4,2	II.
Uruguay	7,3	6,4	6,4	II.	33,8	8,3	18,0	III.
Venezuela	56,6	105,0	55,0	IV.	106,0	168,0	85,0	V.
3. NEAR EAST			139,7				348,0	
N.E. Africa			46,7				112,0	
Egypt	136,8	13,5	39,0	III.	214,9	21,6	80,0	V.
Libya	8,1	2,3	5,7	II.	17,9	4,6	12,0	III.
Sudan	21,5	-	2,0	II.	79,2	-	20,0	III.

Table 4.2-3 /cont'd/

1000 t K_2O

Country	1990				2000			
	Estimates			Cat.[d]	Estimates			Cat.[d]
	FAO[a]	UNIDO			FAO[a]	UNIDO		
		b	c			b	c	
N.E. Asia			93,0				236,0	
Afghanistan	5,0	-	1,1	II.	28,7	-	4,5	II.
Cyprus	4,6	3,5	3,7	II.	8,1	5,6	5,6	II.
Iran	172,3	-	15,0	III.	515,8	-	80,0	V.
Iraq	21,3	5,3	5,3	II.	119,4	10,0	12,0	III.
Jordan	2,8	3,2	2,2	II.	4,8	6,4	4,8	II.
Lebanon	13,2	12,8	10,6	III.	28,8	25,6	25,6	III.
Saudi-Arabia	3,1	-	2,5	II.	14,3	-	11,0	III.
Syria	14,2	5,1	8,0	II.	20,4	10,2	16,0	III.
Turkey	334,5	44,0	44,0	IV.	518,3	70,0	75,0	V.
Yemen AR	0,2	-	0,4	I.	1,0	-	0,9	I.
Yemen PDR	0,2	-	0,2	I.	0,7	-	0,6	I.
4. FAR EAST			4025,2				7459,2	
South Asia			1550,8				2926,0	
Bangladesh	50,9	50,9	88,6	V.	199,2	102,0	118,0	VI.
India	1948,1	889,0	1363,0	VI.	4560,2	1422,0	2620,0	VI.
Nepal	2,8	-	2,2	II.	8,7	-	7,0	II.
Pakistan	811,5	13,3	45,0	IV.	1835,8	21,3	90,0	V.
Sri Lanka	64,8	57,0	52,0	IV.	114,6	90,0	91,0	V.
East and South-East Asia			2474,4				4533,2	
Burma	24,0	7,0	17,0	III.	47,7	11,0	33,0	III.
China	-	182,0	1400,0	VI.	-	363,0	2800,0	VI.
Indonesia	370,0	186,0	186,0	VI.	608,0	370,0	370,0	VI.
Kampuchea DM	0,4	-	0,4	I.	1,1	-	1,1	II.
Korea DPR	99,7	119,0	119,0	VI.	127,5	165,0	156,0	VI.
Korea Rep.	225,6	312,0	226,0	VI.	265,4	499,0	265,0	VI.
Laos	-	-	-	I.	0,1	-	0,1	I.

Table 4.2-3 /cont'd/

1000 t K_2O

Country	1990				2000			
	Estimates			Cat.[d]	Estimates			Cat.[d]
	FAO[a]	UNIDO			FAO[a]	UNIDO		
		b	c			b	c	
Malaysia	555,6	436,0	280,0	VI.	1255,0	698,0	450.0	VI.
Philippines	191,4	112,0	112,0	VI.	483,7	180,0	180,0	VI.
Thailand	76,4	59,0	59,0	IV.	128,1	118,0	118,0	VI.
Viet Nam	93,7	-	75,0	V.	199,3	-	160,0	VI.
TOTAL			6461,0				12072,7	

Remarks:

a - "Agriculture toward 2000" FAO, Scenario "A" - Potential Demand Forecast.

b - Market study of mini-fertilizer plants for developing countries by Shu Lin Peng Ph.D. for UNIDO, September 1982.

c - Demand forecast specially prepared by the Hungarian Chemical Industries Engineering Center /VEGYTERV/, Budapest, for this study.

d - Consumption categories:

Category	Consumption /tpy K_2O/
I.	less than 1000
II.	1000 - 10000
III.	10000 - 40000
IV.	40000 - 70000
V.	70000 - 100000
VI.	over 100000

Table 4.2-4

Share of the developing countries,according to the consumption categories of N fertilizer,by regions

/1990/

Region	I.		II.		III.		IV.		V.		VI.		VII.		Total	
	X	%	X	%	X	%	X	%	X	%	X	%	X	%	X	%
1. AFRICA	4	10,8	16	43,2	10	27,0	2	5,4	1	2,7	4	10,8	-	-	37,0	100
North-West Africa	-	-	-	-	-	-	1	33,4	-	-	2	66,6	-	-	3,0	100
West Africa	1	7,1	9	64,4	3	21,4	-	-	-	-	1	7,1	-	-	14,0	100
Central Africa	I	14,3	4	57,1	2	28,6	-	-	-	-	-	-	-	-	7,0	100
East and S.Africa	2	15,4	3	23,1	5	38,4	1	7,7	1	7,7	1	7,7	-	-	13,0	100
2. LATIN AMERICA	-	-	5	20,8	5	20,8	5	20,8	3	12,6	3	12,5	3	12,5	24,0	100
Central America	-	-	-	-	2	28,6	3	42,8	1	14,3	-	-	1	14,3	7,0	100
Caribbean	-	-	1	25,0	1	25,0	1	25,0	-	-	-	-	1	25,0	4,0	100
South America	-	-	4	30,8	2	15,4	1	7,6	2	15,4	3	23,2	1	7,6	13,0	100
3. NEAR EAST	-	-	2	14,3	4	28,6	2	14,3	1	7,1	2	14,3	3	21,4	14,0	100
N.E. Africa	-	-	-	-	-	-	1	33,4	1	33,3	-	-	1	33,3	3,0	100
N.E. Asia	-	-	2	18,2	4	36,3	1	9,1	-	-	2	18,2	2	18,2	11,0	100
4. FAR EAST	1	6,3	-	-	2	12,5	-	-	-	-	2	12,5	11	68,7	16,0	100
South Asia	-	-	-	-	1	20,0	-	-	-	-	1	20,0	3	60,0	5,0	100
East and S-E Asia	1	9,1	-	-	1	9,1	-	-	-	-	1	9,1	8	72,7	11,0	100
Total	5	5,5	23	25,3	21	23,1	9	9,9	5	5,5	11	12,1	17	18,6	91,0	100

Remarks: The 91 of developing countries that projection of consumption to 2000 have been made for are included.

X - countries in number

Table 4.2-5

Share of the developing countries, according to the consumption categories of N fertilizer, by regions

/2000/

Region	I.		II.		III.		IV.		V.		VI.		VII.		Total	
	X	%	X	%	X	%	X	%	X	%	X	%	X	%	X	%
1. AFRICA	2	5,4	15	40,6	8	21,6	3	8,1	2	5,4	4	10,8	3	8,1	37	100
North-West Africa	-	-	-	-	-	-	-	-	-	-	1	33,4	2	66,6	3	100
West Africa	-	-	9	64,4	2	14,3	1	7,1	1	7,1	-	-	1	7,1	14	100
Central Africa	1	14,3	4	57,1	2	28,6	-	-	-	-	-	-	-	-	7	100
East and Southern Afr.	1	7,7	2	15,4	4	30,7	2	15,4	1	7,7	3	23,1	-	-	13	100
2. LATIN AMERICA	-	-	5	20,8	2	8,4	4	16,6	1	4,2	6	25,0	6	25,0	24	100
Central America	-	-	-	-	-	-	3	42,8	-	-	3	42,8	1	14,4	7	100
Caribbean	-	-	1	25,0	1	25,0	-	-	1	25,0	-	-	1	25,0	4	100
South America	-	-	4	30,8	1	7,6	1	7,6	-	-	3	23,2	4	30,8	13	100
3. NEAR EAST	-	-	2	14,3	2	14,3	3	21,4	1	7,1	2	14,3	4	28,6	14	100
N.E. Africa	-	-	-	-	-	-	1	33,4	-	-	1	33,3	1	33,3	3	100
N.E. Asia	-	-	2	18,2	2	18,2	2	18,2	1	9,1	1	9,1	3	27,2	11	100
4. FAR EAST	1	6,3	-	-	1	6,3	1	6,3	-	-	-	-	13	81,1	16	100
South Asia	-	-	-	-	-	-	1	20,0	-	-	-	-	4	80,0	5	100
East and South-East A.	1	9,1	-	-	1	9,1	-	-	-	-	-	-	9	81,8	11	100
Total	3	3,3	22	24,2	13	14,3	11	12,0	4	4,4	12	13,2	26	28,6	91	100

Remarks: The 91 of developing countries that projection of consumption to 2000 have been made for are included.

X - countries in number

Table 4.2-6

Share of the developing countries, according to the consumption categories of P_2O_5 fertilizer, by regions

/1990/

Region	I.		II.		III.		IV.		V.		VI.		Total	
	X	%	X	%	X	%	X	%	X	%	X	%	X	%
1. AFRICA	3	8,1	20	54,1	9	24,3	2	5,4	1	2,7	2	5,4	37	100
North-West Africa	-	-	-	-	-	-	1	33,4	-	-	2	66,6	3	100
West Africa	-	-	10	71,5	3	21,4	-	-	1	7,1	-	-	14	100
Central Africa	1	14,3	5	71,4	1	14,3	-	-	-	-	-	-	7	100
East and Southern Africa	2	15,5	5	38,4	5	38,4	1	7,7	-	-	-	-	13	100
2. LATIN AMERICA	-	-	7	29,2	7	29,2	4	16,6	-	-	6	25,0	24	100
Central America	-	-	-	-	4	57,1	2	28,6	-	-	1	14,3	7	100
Caribbean	-	-	2	50,0	1	25,0	-	-	-	-	1	25,0	4	100
South America	-	-	5	38,5	2	15,4	2	15,4	-	-	4	30,7	13	100
3. NEAR EAST	1	7,1	4	28,7	3	21,4	3	21,4	-	-	3	21,4	14	100
N.E. Africa	-	-	1	33,4	-	-	1	33,3	-	-	1	33,3	3	100
N.E. Asia	1	9,0	3	27,3	3	27,3	2	18,2	-	-	2	18,2	11	100
4. FAR EAST	2	12,5	1	6,3	-	-	2	12,5	1	6,3	10	62,4	16	100
South Asia	-	-	1	20,0	-	-	1	20,0	-	-	3	60,0	5	100
East and South-East Asia	2	18,2	-	-	-	-	1	9,1	1	9,1	7	63,6	11	100
Total	6	6,6	32	35,2	19	20,9	11	12,1	2	2,2	21	23,0	91	100

Remarks: The 91 of developing countries that projection of consumption to 2000 have been made for are included.

X - countries in number

Table 4.2-7

Share of the developing countries, according to the consumption categories of P_2O_5 fertilizer, by regions

/2000/

Region	I.		II.		III.		IV.		V.		VI.		Total	
	X	%	X	%	X	%	X	%	X	%	X	%	X	%
1. AFRICA	2	5,4	16	43,2	9	24,3	3	8,1	2	5,4	5	13,6	37	100
North-West Africa	-	-	-	-	-	-	-	-	-	-	3	100,0	3	100
West Africa	-	-	9	64,3	2	14,3	2	14,3	-	-	1	7,1	14	100
Central Africa	1	14,3	4	57,1	2	28,6	-	-	-	-	-	-	7	100
East and Southern Africa	1	7,7	3	23,1	5	38,4	1	7,7	2	15,4	1	7,7	13	100
2. LATIN AMERICA	-	-	6	25,0	4	16,7	4	16,7	3	12,5	7	29,1	24	100
Central America	-	-	-	-	3	42,8	1	14,3	2	28,6	1	14,3	7	100
Caribbean	-	-	1	25,0	1	25,0	1	25,0	-	-	1	25,0	4	100
South America	-	-	5	38,5	-	-	2	15,4	1	7,6	5	38,5	13	100
3. NEAR EAST	-	-	4	28,6	3	21,4	1	7,1	2	14,3	4	28,6	14	100
N.e. Africa	-	-	1	33,4	-	-	-	-	1	33,3	1	33,3	3	100
N.E. Asia	-	-	3	27,2	3	27,3	1	9,1	1	9,1	3	27,3	11	100
4. FAR EAST	1	6,2	1	6,2	1	6,2	-	-	1	6,2	12	75,2	16	100
South Asia	-	-	-	-	1	20,0	-	-	1	20,0	3	60,0	5	100
East and South-East Asia	1	9,1	1	9,1	-	-	-	-	-	-	9	81,8	11	100
Total	3	3,3	27	29,7	17	18,7	8	8,8	8	8,8	28	30,7	91	100

Remarks: The 91 of developing countries that projection of consumption to 2000 have been made for are included.

X - countries in number

Table 4.2-8

Share of the developing countries, according to the consumption categories of K_2O fertilizer, by regions

/1990/

Region	I.		II.		III.		IV.		V.		VI.		Total	
	X	%	X	%	X	%	X	%	X	%	X	%	X	%
1. AFRICA	8	21,6	19	51,4	8	21,6	2	5,4	-	-	-	-	37	100
North-West Africa	-	-	-	-	1	33,3	2	66,7	-	-	-	-	3	100
West Africa	3	21,4	8	57,2	3	21,4	-	-	-	-	-	-	14	100
Central Africa	2	28,6	4	57,1	1	14,3	-	-	-	-	-	-	7	100
East and Southern Africa	3	23,1	7	53,8	3	23,1	-	-	-	-	-	-	13	100
2. LATIN AMERICA	1	4,2	7	29,2	11	45,7	1	4,2	1	4,2	3	12,5	24	100
Central America	-	-	-	-	6	85,7	-	-	-	-	1	14,3	7	100
Caribbean	-	-	2	50,0	1	25,0	-	-	-	-	1	25,0	4	100
South America	1	7,7	5	38,5	4	30,7	1	7,7	1	7,7	1	7,7	13	100
3. NEAR EAST	2	14,3	8	57,2	3	21,4	1	7,1	-	-	-	-	14	100
N.E. Africa	-	-	2	66,7	1	33,3	-	-	-	-	-	-	3	100
N.E. Asia	2	18,2	6	54,5	2	18,2	1	9,1	-	-	-	-	11	100
4. FAR EAST	2	12,5	1	6,2	1	6,2	3	18,8	2	12,5	7	43,8	16	100
South Asia	-	-	1	20,0	-	-	2	40,0	1	20,0	1	20,0	5	100
East and South-East Asia	2	18,2	-	-	1	9,1	1	9,1	1	9,1	6	54,5	11	100
Total	13	14,3	35	38,5	23	25,3	7	7,7	3	3,3	10	10,9	91	100

Remarks: The 91 of developing countries that projection of consumption to 2000 have been made for are included.

X - countries in number

Table 4.2-9

Share of the developing countries,according to the consumption categories of K$_2$O fertilizer,by regions

/2000/

Region	I.		II.		III.		IV.		V.		VI.		Total	
	X	%	X	%	X	%	X	%	X	%	X	%	X	%
1. AFRICA	5	13,5	17	46,0	9	24,3	3	8,1	1	2,7	2	5,4	37	100
North-West Africa	-	-	-	-	-	-	1	33,3	-	-	2	66,7	3	100
West Africa	2	14,3	8	57,2	2	14,3	1	7,1	1	7,1	-	-	14	100
Central Africa	1	14,3	5	71,4	1	14,3	-	-	-	-	-	-	7	100
East and Southern Africa	2	15,4	4	30,7	6	46,2	1	7,7	-	-	-	-	13	100
2. LATIN AMERICA	-	-	7	29,2	9	37,5	2	8,3	2	8,3	4	16,7	24	100
Central America	-	-	-	-	5	71,4	1	14,3	-	-	1	14,3	7	100
Caribbean	-	-	2	50,0	1	25,0	-	-	-	-	1	25,0	4	100
South America	-	-	5	38,5	3	23,0	1	7,7	2	15,4	2	15,4	13	100
3. NEAR EAST	2	14,3	3	21,4	6	42,9	-	-	3	21,4	-	-	14	100
N.E. Africa	-	-	-	-	2	66,7	-	-	1	33,3	-	-	3	100
N.E. Asia	2	18,2	3	27,3	4	36,3	-	-	2	18,2	-	-	11	100
4. FAR EAST	1	6,3	2	12,5	1	6,3	-	-	2	12,5	10	62,4	16	100
South Asia	-	-	1	20,0	-	-	-	-	2	40,0	2	40,0	5	100
East and South-East Asia	1	9,1	1	9,1	1	9,1	-	-	-	-	8	72,7	11	100
Total	8	8,8	29	31,8	25	27,5	5	5,5	8	8,8	16	17,6	91	100

Remarks: The 91 of developing countries that projection of consumption to 2000 have been made for are included.

X - countries in number

4.3 Identification of countries according to their raw material potential

The major raw materials are natural gas, naphtha, fuel oil and coal for manufacture of nitrogenous fertilizers; phosphate rock and sulphur for phosphate fertilizers; and potash ores for potash fertilizers.

Though electric power and water can not take as raw materials in a strict sense but they are very important factors and play significant rules in selection of locations of fertilizer plants.

The mined products vary significantly from place to place and contain constituents that can have important effects upon the processes which they are used in. Therefore a change in the source of supply may adversely affect the process leading to lower efficiency and/or loss of output. If a change in supply becomes necessary, careful and lengthy trials of alternative materials should be made.

The main raw materials for this industry can be found in many places of the world, but it is impossible to present more than a rough estimate of reserves of any mineral deposit, particularly in the developing countries. There are two main difficulties.

The first one comes from the lack of information. Large areas of the globe either have not been surveyed at all or have been surveyed inadequately.

The second difficulty is that there is no agreed definition of reserves. Some estimates include the total quantity existing in the deposit whereas others include only that amount which can be obtained by present mining techniques. Others, furthermore count the amount that can be economically extracted. Therefore, the proportion of a deposit included in reserves varies from one to another and would also be affected by changes in mineral market prices or in extraction and mining costs.

Of the various fertilizer raw materials the reserve estimates of phosphate rock, sulphur and coal have the greater margin of uncertainty. The estimates for crude petroleum and, to a lesser degree, natural gas are the most reliable, because of their importance, much attention has been given to these materials and to the technology required for their estimation. It may be, the one for potash is the most reliable because the number of known deposits is relatively small.

Using various sources, in the Appendix 4/3 we show the data of raw materials (production capacities and reserves) in six tables, as follows:

- recent production of natural gas and reserves in developing countries
- recent crude oil production, reserves and refining capacities in the developing countries
- recent production of coal and reserves in the developing countries
- recent production of phosphate rock and reserves in the developing countries
- recent production of potash and reserves in the developing countries
- recent production of sulphur in all forms and reserves in the developing countries.

In Table 4.3-1 the raw material potential of developing countries studied are summarized by regions. It can be seen that almost half of the countries surveyed have natural gas reserves and 48 of them can or would be able to produce crude oil. 40 developing countries surveyed have coal/lignite deposits. However, large areas have not been surveyed because until the beginning of the energy crisis the search for coal has been relatively neglected. It is possible that much more developing countries will have coal deposits when the researches and explorations are made on a wider scale.

The reserves of phosphate rock are widespread. Some 34 countries of the world are producers, and 23 of the developing countries belong to 91 countries studied. Among them Morocco is the most important having about 70 % of total identified reserves. Together with Morocco, 41 developing countries surveyed have phosphate rock. The estimation of reserves varies widely. According to experts, the estimated life of reserves at current production levels should last for about 600 years.

According to FAO statistics, in 1981/82 there were 12 potash producing countries of which two, China and Chile, were developing countries and their production reached 51000 tons K_2O, amounting almost to 0,2 per cent of world production. In addition another 14 countries have potash deposits, among them the former potash producer Congo that plans to develop its closed mine. A number of developing countries plan to begin the potash production, according to their plans. The most important would be Jordan with a total capacity of 1,2 million tpy by 1985.

Sulphur in various forms is widely distributed. It constitutes about 0,1 per cent of the earth'crust, but the value of each form differs greatly for the manufacturers. It is found as elementary sulphur, as metal sulphides in mineral ores, as sulphates, as hydrogen sulphide in natural gas, and as complex organic sulphur compounds in crude oil. All these can be used as sulphur sources but the most important are elementary sulphur, hydrogen sulphide and pyrites.

Table 4.3-1

Number of developing countries surveyed having raw materials for fertilizer production (1983)

Region	Natural gas	Crude oil	Coal	Phosphate rock	Potash
1.) Africa					
North-West Africa	3	3	1	3	2
West Africa	1	7	4	6	–
Central Africa	5	6	3	4	1
East and Southern Africa	1	2	8	6	2
AFRICA TOTAL:	10	18	16	19	5
2.) Latin America					
Central America	1	3	2	2	1
Caribbean	–	1	1	–	–
South America	9	9	7	6	4
LATIN AMERICA TOTAL	10	13	10	8	5
3.) Near East					
N.E. Africa	3	3	–	1	–
N.E. Asia	7	6	2	6	3
NEAR EAST TOTAL	10	9	2	7	3
4.) Far East					
South Asia	3	2	3	2	1
East and South-East Asia	6	6	9	5	2
FAR EAST TOTAL	9	8	12	7	3
TOTAL	39	48	40	41	16

4.4 Identification of countries which could use both mini- and large-fertilizer plants

In any sort of discussion on the economics of small versus large fertilizer plants one advances arguments both for and against.

The supporters of the large plant philosophy emphasize the economics of scale and explain how the capital related charges per ton product are much higher on a small scale plant compared with a large one.

On the other hand, the supporters of mini-plant philosophy emphasize that small plants are easier to operate, the capital investments are less and they are more amenable to "modularisation". Therefore, some of the erection elements can be carried out in the developed location where the equipment comes from. Perhaps the most important argument in favour of the establishment of mini fertilizer plants in developing countries is that plants would and could be located near to the areas of demand. This can be a good alternative in many of developing countries where transportation facilities and the marketing-distribution systems are poor or inadequate.

There is a number of developing countries where both alternatives, mini-scale and large unit, can be considered. They are generally large-sized countries and/or have special circumstances and reasons favouring establishing both large and small plants. Some of them are:

- a vast expanse of territory, a large population, or both
- topographical characteristics,i.e. a lot of islands in Indonesia and in Philippines, or long distances in countries because of their special configurations (Viet-Nam, Burma), etc.

In any case it should be evident that emphasis should be placed on minimizing delivered cost at farm gate rather than on minimum cost at the factory gate. Consequently, in a lot of countries in several regions mini-plants using local resources, supplying local areas, can possibly exist not far from large tonnage units that can play important roles in the supplying of the domestic and export markets.

Table 4.4-1 lists the countries that could use both mini and large fertilizer plants. All available information as well as special considerations mentioned above were taken in compiling this list. It shows that 16 and 10 countries may use both plant sizes for N and P_2O_5, respectively, and 9 countries would be able to establish mini and large units for both main nutrients.

Table 4.4-1

Developing countries that could use both mini and large fertilizer plants

Country	Nitrogen	Phosphorus
Nigeria	+	+
Ethiopia	+	
Mexico	+	
Cuba	+	
Argentina		+
Brazil	+	+
Colombia	+	+
Ecuador	+	
Turkey	+	+
Bangladesh	+	
India	+	+
Pakistan	+	+
Burma	+	
China	+	+
Indonesia	+	+
Malaysia	+	
Viet-Nam	+	+
	16	10

Remarks: medium-size is included in the large one

4.5 Identification of countries according to the types of fertilizers to be produced

During the development of the fertilizer industry a great number of fertilizers have appeared on the market, each containing one, two or three macronutrients, namely nitrogen, phosphorous and potassium. Most of the products came to the market as a result of availability in large quantities of major raw materials, such as ammonia, phosphate rock and sulphuric acid, which could be economically processed into standard fertilizers.

There are two basic types of fertilizers: One is straight fertilizer containing only one nutrient, the other kind is compound fertilizer containing two or more nutrients.

Comparing the production costs of the two main sources of N fertilizer, urea and ammoniumnitrate, based on natural gas it can be demonstrated that the factory cost per ton of N in AN is about 30-40 per cent higher than for N in urea. (See Appendix 3/1). Further, taking into consideration the fact, that a more concentrated product has lower handling and transport cost per ton of N, it can be stated that production and use of urea has an economic advantage. Sometimes this advantage can be neglected for agriculture reasons.

Nearly all phosphate fertilizers are produced in solid forms. The single superphosphate like ammonium sulphate has disadvantage of low nutrient content, but also the advantage of the advantage of obtining sulphur which the others (TSP, DAP, MAP) do not. It cannot be economically transported over long distances but it can compete over short distances. The agronomic differences among the several types of phosphate fertilizers are slight, the choice among them is usually made on economic considerations.

Beside the above mentioned types of fertilizers, there are a lot of others including various kinds of compound fertilizers that are produced in wide range by chemical way or by simple mechanical mixing. On the other hand, there is an increasing interest of liquid fertilizers including aqueous solutions containing nitrogen and suspensions containing two or three main nutrients.

It is important to mention the "secondary nutrients" such as sulphur, calcium, magnesium and "micro-nutrients" such as copper, zinc, molybdenium, etc. However, it is not the task of this study to demonstrate all the possibilities for a developing countries to choose its alternatives in starting the process of domestic production of fertilizers. For this reason in every developing countries analyses are necessary to choose the best solution, taking into consideration all the local circumstances. In this respect a general guideline may be suggested for choosing product-types in mini-fertilizer plants.

As for the straight nitrogen fertilizers, urea and ammoniumnitrate are the advisable products. Ammoniumsulphate production via sulphuric acid manufactured for this purpose is more costly; this material can be counted as industrial by-product.

For the production of phosphate fertilizers on mini-scale, first of all the single superphosphate can be recommended, taking into consideration the short transport distances, its simple manufacturing process, instead of concentrated phosphate fertilizers based on phosphoric acid.

The production of potash will be limited to few developing countries but not on mini-scale.

4.6 Assessment of demand for fertilizers and of potential for small scale fertilizer units in countries identified as potential users of mini-fertilizer plants

4.6.1 Fertilizer production units

There are three means of supplying a country with fertilizers: domestic production, importation and the combination of the two in any ratio. As a rule, domestic production would be advisable if the basic raw material(s) are available. It is a general tendency to try to use as much raw materials as possible locally available even if they are of lower grade or are more expensive.

In the previous chapters surveys have been made of the raw materials' potential in developing countries and forecasts of consumption of fertilizer nutrients for 91 developing countries. Taking into consideration the existing production capacities and those under construction, theoretically, supply/demand balances can be made for each country and region. However, some of the developing countries having large quantities of cheap raw materials have been increasing their productive capacities for export purposes. This trend, will no doubt continue in the future and for this reason surplus capacities can be found on regional and/or subregional scales. The number of mini-plants in the developing countries will depend on their raw material potential and on their efforts to become self-sufficient. In some countries mini-plants will have capacities exceeding demands. It is thought that local surpluses will stimulate demand in these countries.

Estimates of the number of mini-fertilizer production plants for the developing countries by regions are summarized in Tables 4.6-1; 4.6-2; 4.6-3 and 4.6-4. In Table 4.6-1 and 4.6-2 the number of NH_3 mini-plants is proposed to be built in the first and the second decade, respectively, indicating their capacities (150 tpd and 250 tpd) and raw materials (natural gas, fuel oil, coal). Accordingly, toward 1990 85 mini NH_3 plants is forecast, 84 of them for fertilizer purposes. Their combined capacity amounting to 18700 tpd NH_3. The majority, almost three-quarters are based on natural gas, and only 3 of them on hydropower potential.

In the last decade of this century 130 mini NH_3 plants are forecast with a total capacity of 29400 tpd. The majority of them (about 67 per cent) are also based on natural gas but coal as raw material would become more important increasing its share to 19 per cent in 1990 and 28 per cent in the last decade of the century.

In Table 4.6-3 urea and ammoniumnitrate capacities are summarized by regions, adjusting them to the above mentioned NH_3 capacities.

In Table 4.6-4 the number of mini-scale P_2O_5 units are summarized by regions. Each of these plants consists of a single superphosphate plant with a capacity of 500 tpd SSP (90 tpd P_2O_5) and a sulphuric acid plant with a capacity of 200 tpd on the basis of elementary sulphur. 42 units are proposed to be established up to 1990. In the last decade of the century 68 units are forecast, amounting to a total new capacities of 3780 tpd P_2O_5 and 6120 tpd P_2O_5, respectively.

In Appendix 4/4 the countries' demand versus mini-plant capacities are shown for N and P_2O_5 in two tables, respectively, and the balances are summarized by regions.

Table 4.6-1

Estimate of number of mini NH_3 plants that could be established in 91 developing countries toward 1990

Nominal capacity tpd NH_3 Region	coal		nat.gas		fuel oil		Total	Remarks
	150	250	150	250	150	250		
Africa							11	
North-West	-	-	-	-	-	-	-	
West	-	-	-	2	1	-	3	
Central	-	-	4^{*}	-	-	-	4^{*}	*one of them is on hydropower potential
East and Southern	3^{**}	1	-	-	-	-	4^{**}	**one of them not for fertilizer production
Latin America							16	
Central	-	1	-	2	1	-	4	
Caribbean	-	-	-	1^{*}	-	2	3^{*}	*one of them is on hydropower potential
South	-	-	2	7	-	-	9	
Near East							7	
Africa	-	-	1	1	-	-	2	
Asia	-	-	1	4	-	-	5	
Far East							51	
South Asia	-	-	1^{*}	12	-	-	13	*on hydropower potential
East and South-East Asia	5	6	4	20	1	2	38	
Total	8	8	13	49	3	4	85	

Total capacity: 18850 tpd NH_3; of which one plant with a capacity of 150 tpd NH_3 may be built in Burundi for metallurgy purpose.

For fertilizer production: 18700 tpd NH_3

Table 4.6-2

Estimate of number of mini NH_3 plants that could be established in 91 developing countries 1990-2000

Nominal capacity tpd NH_3 Region	coal		nat.gas		fuel oil		Total	Remarks
	150	250	150	250	150	250		
Africa								
North-West	-	-	-	-	-	-		
West	1	-	1	2	2	-	6	
Central	-	-	3	-	-	-	3	
East and Southern	2	3	1	-	-	-	6	
Latin America								
Central	-	1	-	2	1	-	4	
Caribbean	-	-	-	1*	-	2	3*	*one of them on hydropower potential
South	-	7	2	7	-	-	16	
Near East								
Africa	-	-	1	2	-	-	3	
Asia	-	-	2	7	-	-	9	
Far East								
South Asia	-	-	1*	22	-	-	23*	*one of them on hydropower potential
East and Southern East Asia	8	14	5	28	1	1	57	
Total	11	25	16	71	4	3	130	

Total capacity: 29400 tpd NH_3

Table 4.6-3

Estimate of number of mini urea and NH_4NO_3 capacities that could be established in 91 developing countries up to 1990 and 1990-2000

Nominal capacity tpd	up to 1990				1990 - 2000			
	Urea		NH_4NO_3		Urea		NH_4NO_3	
Region	260	440	355	591	260	440	355	591
Africa								
North West	-	-	-	-	-	-	-	-
West	-	1	1	1	1	1	2	1
Central	2	-	2	-	2	-	1	-
East and Southern	1	1	1	-	2	2	2	1
Latin America								
Central	1	1	-	2	1	2	-	1
Carribean	-	1	-	2	-	1	-	2
South	1	4	1	3	1	8	1	6
Near East								
Africa	1	1	-	-	1	2	-	-
Asia	-	2	1	2	1	4	1	3
Far East								
South Asia	-	7	1	5	-	10	1	12
East and Southern East Asia	6	18	4	10	7	23	7	20
Total	12	36	11	25	16	53	15	46

Table 4.6-4

Estimate of number of mini P_2O_5 capacities that could be established in 91 developing countries up to 1990 and 1990-2000

Nominal capacity: 500 tpd SSP /90 tpd P_2O_5 and
200 tpd sulphuric acid based
on elementary sulphur

Region	up to 1990	1990-2000
Africa		
North-West	-	-
West	2	4
Central	1	2
East and Southern	4	5
Latin America		
Central	1	1
Caribbean	1	2
South	8	11
Near East		
Africa	1	2
Asia	3	5
Far East		
South Asia	5	10
East and South-East Asia	16	26
Total	42	68

Total capacity to 1990: 21000 tpd SSP /3780 tpd P_2O_5/
1990-2000: 34000 tpd SSP /6120 tpd P_2O_5/

4.6.2 Fertilizer processing plants and storage facilities

Since fertilizer is a seasonal commodity while its production is usually continuous the marketing, including distribution, regional and/or local storage, is a very important factor which is often given insufficient attention. Too often it is assumed if an adequate amount of fertilizer is produced it will sometimes find its way to the farms. The marketing and distribution system is as important as the production system and should receive equal attention.

The marketing system usually includes facilities for handling and storage of fertilizers in local warehouses, providing a link and a buffer between the continuous production and the seasonal use. Where existing transportation is insufficient, the marketing system also may need to include transport facilities. Of course, in case of mini-plants the transport distances are much shorter than in case of a large tonnage unit.

When local warehouses are established for storage of fertilizers, the location of bulk blending units beside them does not involve high investment. In these units many formulations can be provided by mechanical mixing of straight fertilizers produced in mini-fertilizer plants. In this way two objectives can be achieved. First, there is no need to produce various kind of compound fertilizers with different NPK grades by, generally, complicated processes in mini-plants. And second, the most suitable formulations to the various cultures and soils can be fitted by blending different fertilizer materials in the warehouses.

The capacity of the storehouse and blending unit depends on the area where it is located on. It generally varies from 10000 tpy up to 100000 tpy. Taking into consideration a unit capacity of 10000 tpy and the forecast fertilizer consumption of the developing countries, up to 1990 about 3500 such storage/blending units might be needed. They can cover only the 40 per cent of the total calculated demand. From 1991 to 2000 about 6000 units might be installed. These together can meet requirements at a rate of 70 per cent. It must be, however, mentioned that four large countries, China, India, Brazil, Mexico are not included in the above forecast because they have differences significantly in their circumstances.

Although, these numbers are mechanically calculated it is certain that a lot of such facilities would be established in any way. No accurate estimate can not be made because:

there is no information as to how many units exist or are under construction and in all cases their sizes (capacity) would absolutely depend on the local circumstances (regarding land, transport possibilities etc.).

The storage and distribution system is a very important part of the fertilizer supply and it is sure that a lot of them will be built in many developing countries. However, since the bulk of the investment cost for a unit containing storehouse and blending plant is inserted to the storage facilities, it would be a mistake to neglect the inclusion of blending facilities with the warehouse.

5. FERTILIZER SUPPLY SYSTEM

The question, whether the consumption needs of a developing country be covered through the erection of a local mini-plant, an export-oriented big size plant of a jumbo size serving a whole region or simply through import cannot be decided upon comparing of the technical and economic advantages or disadvantages of the mini-plant only. Long term planning demographic forecasts, food demand, agricultural development plans, raw material resource, foreign trade balance, manpower and technical skill availability, infrastructural development logistics, market organisation, transport, storage, distribution and application together with many other questions need all be considered in order to work out the alternative supply routes and decide upon the right solution.

The establishment of an effective fertilizer supply system in most developing countries is not likely to succeed unless the government assigns it a high priority and adopts polices to expedite its development. This is particularly so in country facing food supply problem, or wanting to exploit fully its agricultural potential.

Estimate of fertilizer demand

It is be assumed that every country has some goals for its agriculture, including supplying enough food crops of appropriate types for its population; supplying nonfood needs such as rubber, cotton, wool, hemp, etc.; and producing cash crops for export of products for which the country has natural advantages. Some approximation of the amount and kinds of fertilizers needed to achieve these goals usually can be formulated provided sufficient agricultural information is available. It must be stressed that for qualitative, as well as for quantitative assessment, only the analytical approach is feasible, every region asks for individual examination, no summarized "national" values will help.

In agricultural development fertilizer use is only one factor among many others: biological methods (seed), plant protection chemicals, irrigation, tillage methods, melioration and many other measures must be applied for optimum results. Use of local nutrient sources (manure etc.) should be also considered. Factors, like the purchasing power of farmers, price policy and government subsidies if not properly considered, can upset the best of forecasts.

Beside the quantitative assessment of the fertilizer needs, it is necessary to determine the right relationship between the different nutrients and the kind of product to be used.

This is a difficult problem and its implications are sometimes not fully appreciated. Usually there are data available on the response of major crops to each of the primary nutrients and to the secondary nutrients. However, with continued fertilizer use of one or two nutrients, other nutrients may become more and more deficient. By means of soil analyses and crop requirements or if available from long-term test data, the right nutrient balance can be anticipated.

The choice of the fertilizer product forms is also a complex problem. Soil composition, crop, agricultural and application methods, as well as fertilizer product properties (compensation, hygroscopicity, particle size etc.) are the technical factors to be considered. Raw material and other resources available have also their influence on the result, the economics, where all this factors, expressed in money terms play their role together with prices, shipping and other cost, have a decisive role.

In summary, the choice of type of fertilizer should be made in cooperation with agronomists, engineers, and marketing specialists with a view to determining the most economical means for supplying all needed nutrients at the farm level while making the best use of the country's resources. The resulting decision will involve in most cases some compromise between agronomic effectiveness and cost or between production and distribution costs. Usually no clear decision is possible in favour of one type of product, but several kind of fertilizer will be needed in a given proportion.

A detailed study and its conclusions on the policy to be adopted with all the possible consequences considered will be of great help for a government aiming at the fostering of an adequate fertilizer supply with its own means: loans, subsidies, levies, taxes, custom duties, etc.; in order to influence the market forces in the right direction.

Marketing and Distribution System

Marketing, including distribution, regional and local storage, and retail outlets of fertilizers, are very important aspects which are often given insufficient attention.

Many developing countries have very poor transportation systems which are already overloaded. In some remote regions of large countries, the cost of transportation far outweighs the cost of fertilizer production. Where existing transportation is inadequate, the marketing system also may need to include transport facilities such as trucks, barges or railcars. These facilities may also be used for carrying grain or other agricultural products to the market. One of the most pressing problems in many developing countries is improvement of the transportation facilities - railroads, highways, waterways, harbours, etc. Such facilities are vital for marketing fertilizers as well as agricultural products. It seems futile to build large fertilizer plants when the infrastructure is inadequate to distribute their production. Development of the infrastructure may well be such an enormous job that the building of numerous smaller plants would provide a more economical and practical alternative.

The marketing system usually include physical facilities for storage of fertilizers in regional, district, and local warehouses.

It is of vital importance to develop a logistics system that will ensure that fertilizer of the right kind is available to farmers in the right amount at the right time. For such a system it is first necessary to estimate the requirements of each region and district in detail including kinds of fertilizers required, quantity of each and the time when each is required. When this information is at hand, a system of regional and district distribution centers can be set up with adequate storage facilities at each center and retail outlets can be identified or established. Transportation of fertilizers to the distribution centers are also to be solved.

In the fertilizer marketing system, physical facilities for transport, storage and distribution, and the necessary skills involved in agricultural organisation and administration should be integrated to serve all identical needs of agriculture.

This studies and their implementation are usually done in the developed countries by the fertilizer manufacturers or by separate wholesale and distributor organisations or by farmer cooperatives. In the developing countries it seems advisable for the authorities to work out the plans and according to the local economic conditions, leave the realisation to the private capital encouraged by government or incentives partly or wholly take in hand the realisation, too.

Regardless of the source of the fertilizer supply the transport, storage and handling system must correspond to the fertilizer need. The quantities to be transported, the shipping distances and the location of warehouses and their capacity, however, is greatly influenced by these sources. Different supply schemes would be needed to correspond to import-based alternatives as against home produced goods in big, centralised plants or in mini-plants situated close to local markets. These differences in the marketing system will often play an important role in tilting the balance in favour of one or other solution.

Natural Resources

A detailed inventory of a country s natural resources is helpful in planning a fertilizer industry. Unfortunately, most developing countries and many developed countries have incomplete knowledge of their mineral resources. Since thorough exploration of mineral resources is very expensive, it is not surprising that very little is known about the mineral content of much of the earth s crust.

While short-term plans must be based on currently known resouces, each country would need to have long-range plans to gather as much information as possible about its mineral resources.

Infrastructure

Although three of the seven aspects of the infrastructural problems defined by the consecutive UNIDO Consultation Meetings on the fertilizer industry have been mentioned just now, it seems adequate to give here the full list:

1. Transportation infrastructure (roads, railways, port facilities, railway rolling stock, ships);

2. Utilities infrastructure (power supply, water supply, and a drainage and sewage system);
3. Raw materials infrastructure (critical raw material inputs, particularly feedstocks);
4. Marketing infrastructure (storage facilities and a distribution network that would make it possible for the product to reach the farms);
5. Infrastructure of agricultural extension services and modern agronomic practices;
6. Human infrastructure (entrepreneurial skills, managerial skills, and maintenance and operation skills);
7. Policy infrastructure (the broad framework of government planning, laws, and pricing and economic policies).

To this list, this study deemed necessary to add one more:

8. Manufacturing infrastructure for equipment and machine replacement, spare part production and maintenance works.

From this list, 1, 3 and 4 have been discussed. The others also must be examined carefully when setting up a national (or regional) fertilizer supply plan. The numerous well known examples of plants built without adequate infrastructure demonstrate well enough how the best and most expensive production facilities can be doomed to inefficiency for lack of the necessary infrastructure. Different types of fertilizer plants have widely differing infrastructural requirements. A 1000 tpd ammonia plant is very demanding both in quantity and quality in water supply, agricultural services, marketing, maintenance and operation skills and uninterrupted power supply, etc. The problems posed by a mini-ammonia plant are at least one magnitude lower.

The costs involved in establishing an adequate infrastructure are usually so high that it can only be supported on a national level.

When setting up a fertilizer supply system usually a very important cost factor influencing the decision is the infrastructure needed. In this study account was taken of the different factors in calculating the full investment costs from battery limit costs for big and small plants as well as for seaside and remote locations. (See Chapter 1.1 and Appendix 3/1).

Production Facilities

With the data and results mentioned above at hand, the different solutions for the fertilizer supply or a combination of them can be investigated. These are

- import of ready-made fertilizer product
- import of some intermediate product to be processed in the country (this can extend from ammonia or phosphoric acid for fertilizer production to different single fertilizers for compounding or simple bagging)
- fertilizer production in the country.

For this last alternative several cases will be investigated: big central plants and local small ones with all the relevant factors: training, maintenance, spare parts, onstream factor, infrastructural needs etc.; accounted for. Different locations for the production plants, regional cooperation or export possibilities present also several alternatives.

The viable alternatives can be selected only by careful analysis of the local conditions - no general rule exist.

For every production route, the capital and operation costs can be now computed from the raw material source until the product reaches the farm-gate. Costs and incomes in this case cannot be average values or general factors: transportation, storage, infrastructure, offsites etc., for every item, and with the time factor and the corresponding interest rates will be evaluated.

Modelling

When for all possible alternatives the whole cost structure is composed, it is easy to construct the supply model. The individual alternatives have to be complemented by the other technical and economic features which have not yet been taken into account. These features are either of limiting nature: availability of given raw materials, infrastructural services etc., or should have a special (higher or lower) effect on the decision, which could be provided for by application of factors. The whole exercise can be optimized by the linear programming method. (See Annex 3/2).

Optimization could aim at different goals: minimum investment, minimum fertilizer supply cost, minimum foreign currency utilisation etc., or a combination of different aims, expressed in mathematical form by the objective function.

The computer-aided linear programming methods deliver for cash optimization goal a model, which is usually composed from different supply routes in a given proportion (e.g. import, local production in small, resp. big plants). It is very easy to have quite a big number of "runs" for different "aims" and/or different starting conditions (price structure, etc.). Sensitivity analysis is possible to estimate how raw material or product price variations will influence any decision.

Decision-making

Models and computer are very helpful tools - but only tools. Every model and optimisation result will have the same validity and accuracy level as its input data. Known the relative "accuracy" (or better to say inaccuracy) of the forecasts for five - ten - fifteen years ahead, the results of this work should not be taken literally at their face value, but indications for a right decision.

The gathering and detailed analysis of all the background information needed, the evaluation, selection and processing until the final model as well as the interpretation of the results is a very demanding task even for experienced and skilled people. Many developing countries have adequate experience and knowledge in this field; they usually will have already elaborated such a supply system. Beginners in this field would be advised to rely on the help of some knowledgeable other developing country or to use the good services of reliable experts, possibly through the relevant international organisations such as UNIDO.

The national (or regional) supply system is a prerequisite and cannot be a substitute of à feasibility study for every project proposed in the overall scheme. The individual feasibility study, worked out. by much more detailed technical and economic analysis will serve as basis for the final decision on the plant size, location, the process to be used, the product to be manufactured etc.

6. IMPLEMENTATION OF MINI FERTILIZER PLANTS

6.1 General approach

Once the feasibility of a mini fertilizer plant has been established, the procedure for its implementation will start.

Mini-plants will be presumably realised in countries having already broad experience in the fertilizer industry like China, India, Mexico etc., but also at the other end of this line in countries with no fertilizer industry at all.

The realisation of the project will accordingly adopt one of the following forms:

- turn-key plant delivered from a foreign country,
- project realised in cooperation with a foreign (developed or developing) country,
- process, know-how and basic engineering delivered from a foreign country; procurement, erection realised by a home organisation.

Turn-key approach will be chosen by the less experienced countries. It can be safely assumed, that serious competition will occur between contractors from different countries and as a result in every case new developments will be found to improve the performance and thus the economics of the plant offered. Already exist many possibilities to introduce improvements in the existing processes and new processes or process steps are constantly emerging.

The same situation will occur if only process, know-how and basic engineering is the scope of the tender.

Standardisation

Efficiency and competitiveness of a proposed process will depend to a great extent closely following the approach of the optimum conditions: but most of them differ from case to case: local raw materials, meteorological and geographical parameters, services will influence not only the dimensioning of the individual items of equipment but to a certain extent the flowsheet, too.

The capacity of the mini-plants to be realised must usually correspond to the raw material resources, or market limitations or both. It seems not reasonable to suppose that one or two fixed sizes will satisfy all requirements.

Process development and engineering is in our days very different from the classic way of the fifties. Even before the first commercial realisation a computer model is worked out for the whole process. This model undergoes constant improvement in the light of the industrial experience feed back to the engineering services. For every actual case the relevant starting data are fed in and a "tailor made" variant of the process is computed. In most cases only minor variations in reactor volume, heat exchanger size or capacity (in a given range) are needed but major differences (air cooling versus water cooling, different drives, e.g. different reformer furnace constructions etc.) are also possible. The bulk of the engineering cost comes from the first stage: the process development and model construction. The individual modified application do not need appreciable engineering work and cost, but evidently the first realisation cannot bear all the original development costs, it has to be spread over all the projects realised. By this way, the individual tailor made design for every case presents no financial burden, causes no delay and allows for the optimum solution between the limits set by the model. It is obvious, that even the layout the piping and many of the detailed process engineering package will remain superficially the same and for everybody not going into details, the plants will seem to be "standard" plants, as it is the case with the 1000 tpd ammonia units, where in reality among the very numerous plants delivered by the same contractor it would be hardly possible to find two really identical ones.

The process engineering package is the basis for the procurement of the necessary equipment, machines, instruments etc., either by the contractor (turn-key contract) or by the client (basic engineering services). In both cases, to make the project competitive the invited manufacturers will work out the detail engineering, or will offer their proprietary design for machines, instruments etc. Practical experience shows that the different manufacturers offer different designs for the same purpose? Decision, on what to buy will in both cases depend not only on technical considerations, but price, transport, spare part services, credit and other factors. Therefore - as it is the case with all plants --in different places different individual equipment etc., will be found in basically the same kind of plant.

It seems therefore, that every effort to create a "standard" mini-plant design would reduce competition and technical development and present little economic advantage.

This study recommends to promote and encourage the development work on mini-plant processes going on in different developed and developing countries, in order to enable them to offer competitive, economically sound processes for the interested buyers. This together with the possible help that can be provided by international organisations like UNIDO in preparing feasibility studies, tender documents and evaluation would assure the best technical and economic solution for every individual case.

Prefabrication

Local work on site is always a difficult problem in developing countries, particularly in remote locations. Lack of skilled manpower, high expatriate costs, difficult local conditions load to serious delays, inadequate quality and other difficulties in the realisation of new projects.

An obvious way to reduce onsite construction and assembly time is in remote locations with engineering infrastructural support to build a plant in the form of prefabricated units or modules in the works of a fabricator and transport them to the site. However, this is not as easy as it seems. Process plants are usually complex and assemblies of piping and precision equipment, such as instruments, pumps and other rotating machines is a difficult task. Attempts to ship subassemblies of this nature (especially as deck cargo on standard ocean-going vessels) and transport them overland frequently result in considerable damage, with consequent lose in time and in extra cost. Furthermore, transfer from ship to land transport is often hampered by lack of suitable gear. Therefore, adoption of prefabrication under such conditions would be limited to relatively light loads of robust equipment.

Several new methods of prefabricating fertilizer plants or modules have been proposed, and some have been used to construct most of the plants in industrial facilities where it can be done faster, better, and cheaper than at remote locations. The plant or module is then transported to the site and assembled. Prefabrication of production facilities is currently finding extensive use in many fields, and its application to fertilizer plants appears feasible. There-form, it seems appropriate to examine the feasibility of prefabricating fertilizer plants in more detail.

It should be mentioned however that the principle of shipping prefabricated process modules is not new. Contractors were supplying small "packaged" ammonia plants of 50- to 100-tpd capacity as long as 20 years ago. Packaged urea plants of matching capacity are also available. Such installations, consisting of about 17 skid-mounted assemblies weighing 20-40 tons each, which are then assembled on site, require less preparation and civil construction work and less space.

Besides ammonia and urea skid-mounted nitrogen plants, contractors have constructed a number of skid-mounted granulation plants in South America for the manufacture of NPK fertilizers. The capacity of these plants ranges from about 5 to 20 tpd and they serve a regional agricultural center or small market logistically separated from larger agricultural producing areas or markets.

This kind of prefabrication is quite different from the barge-mounted, ocean platform-mounted or other similar methods for large size plants and therefore this study will not dwell on these latter methods which are irrelevant for mini-plants.

The advantages of the skid-mounted method of construction are self-evident.

1. Construction can be undertaken under controlled conditions of quality, labour and material cost.
2. Skilled shop labour rates and overheads are often lower than skilled field labour rates for identical work.
3. Work planning is usually easier under shop conditions, thereby helping to minimize labour costs.
4. Usually, modules can be thoroughly tested before shipment to site.
5. Saving in plant construction time is possible.

The disadvantages are non the less obvious:

1. Overall cost is generally higher.
2. Transport problems are in remote locations bigger.

3. Skids with 20-30 tons each are generally too small for the size of plant considered in this study (e.g. 250 t/day ammonia).
4. Skid-mounting impress a lay-out with the minimum space requirements. Therefore for operation, maintenance and repair usually less space is available and it is therefore more difficult to execute these operations.
5. In all locations, but in developing countries in particular less training possibility is offered by the local erection work to the future.

In every case a detailed analysis of all factors involved should decide on the degree of prefabrication to be adopted.

It should be stressed that the alternative to skid mounted erection method is not the original, old way of shipping half-ready individual items to the site. Prefabrication (e.g. towers delivered complete with isolation and connecting pipework) is in all cases necessary for equipment, machines and piping alike. The optimum degree of prefabrication should be defined individually for every case, but at the very beginning, since switch-over during implementation to another form of erection would be very costly.

6.2 Supply potential of small scale fertilizer plants. Possible form of cooperation among developing countries

In order to build small-scale fertilizer plant, the following items must be provided:

- process know-how and engineering
- equipment
- contracting-procurement, erection
- training.

As was indicated in Chapter 6.1 in a turn-key contract, all four main components can be purchased in one package. In this case, the supplier must have access to all of them. In the other cases different potential suppliers can be invited, having possibilities only for selling one or another part of the above services. Therefore the supply potential available for the two cases will be totally different.

Many contractors from the developed countries are capable of delivering small-scale plants on a turn-key basis. They exist - practically in most developed country - and have impressive reference lists. Many others have the capacities to enter in this field with wide experience in large-scale plants. They need only to be persuaded that sufficient demand will be there to justify the expenses required to develop a mini-plant flowsheet. This is applicable mainly to ammonia, for all the other fertilizer products, practically no difference can be found between big and small plants and all contractors can offer mini--plants.

The same situation is characteristic for the supply of equipment, machines and instruments necessary for the mini-plants. The number of the potential suppliers is even greater here. Therefore, it seems, the procurement will not be hampered by lack of suppliers or of competition, even if the buyer has to limit its procurement basis to a few developed countries.

This situation is, however, different with regard to possible suppliers from the developing countries. Process and equipment delivery possibilities for the different fertilizers should be investigated separately in order to formulate a clear picture.

Ammonia and ammonia-processing is a field where very few developing countries have proprietary processes and know-how. Perhaps the People's Republic of China is the only one. Several others, however, have capable engineering and contracting organisations with sufficient experience in this field such as India and Mexico. These organisations can provide the necessary services for erection and start-up, too. Training possibilities exist in quite a number of countries: having similar mini-plants.

Phosphate fertilizers present a somewhat better picture. Due to the phosphate rock deposits, several, mainly North African countries have facilities, experience and even processes for the mini-plants and can supply engineering and other services.

Due to the very broad spectrum of the equipment needed for a fertilizer plant; nearly every kind of capital good is necessary from heat exchangers through pumps, compressors to electric motors, gears and material handling equipment and instruments it would be impossible to give a complex picture on the delivery possibilities offered by the developing world. The rapid improvement occurring in the manufacturing capability of many a country would make this attempt obsolate in a very short time. Therefore, this study refers to the "Catalogue of Technical Capabilities in Developing Countries" to be compiled, annually updated and circulated by UNIDO. This catalogue described the specific areas in the development of the fertilizer industry in which developing countries have sufficient experience and technical competence to offer cooperation to other countries.

This cooperation can be extended to the following areas:

(a) Continuation of fertilizer supply and production planning for a given region.

(b) Common realisation of mini fertilizer projects either:

  (ba) where one plant could more economically serve to supply an agricultural area extending in the territory of two or more countries

  (bb) where the project could be advantageously implemented by technical cooperation among the interested parties. Examples of cooperation possibilities include delivery of know-how, engineering, procurement, equipment, training and services or even turn-key projects realised together.

(c) Financial cooperation, where the financing of mini-plants in one country could be compensated by raw material or product export.

(d) Transfer of knowledge and experiences in planning, erection, operation and maintenance from the countries that have established fertilizer industry to the beginners.

(e) Training of the future staff of mini-plants in countries having already such facilities.

Cooperation on a regional level would be the best way to start with and could be extended to global dimensions. The different regional organisations: Arab Federation of Chemical Fertilizer Producers, Central American Economic Integration, and other African and Asian organisations, similar to the two above mentioned, have made encouraging steps and registered promising results in other fields. The extension of their activity to the mini-fertilizer plants should be encouraged.

6.3 Estimate of investment needs

6.3.1 Estimate of the investment cost for the supply of typical mini-fertilizer plants

The investment and production costs of several process technologies for all fertilizer production steps are calculated and discussed in Chapter 3 and in Appendix 3/1. These costs are considered for some unit-capacities (small and large) and for three locations (developed: West-Europe, developing: seaside and remote locations).

From data above mentioned, in Table 6.3-1 the investment costs of typical mini-fertilizer units in developing countries are summarized for the three main fertilizer products (urea, ammoniumnitrate and single superphosphate), according to raw materials and locations, and for storehouse with bulk blending unit according to locations. By all means, these investment costs are the total fixed capital costs including the cost of each technological steps (e.g. in case of ammoniumnitrate: ammonia, nitric acid, ammoniumnitrate) and necessary offsites, but excluding working capital.

Table 6.3-1

Investment costs of typical mini-fertilizer plants in developing countries

(million US Dollar; in 1983)

Nitrogen-fertilizer units

Location	Seaside				Remote			
Product	Urea		AN		Urea		AN	
Nominal capacity tpd	260	440	355	591	260	440	355	591
Raw materials								
Natural gas	57	80	88	125	66	94	102	147
Fuel oil	62	87	93	133	72	103	108	156
Coal	78	109	109	155	91	128	127	181

Phosphate-fertilizer units

Capacity	Seaside location	Remote
500 tpd SSP + 200 tpd H_2SO_4	18	21

Storehouse and bulk blending units

Capacity	Seaside location	Remote
10 000 tpd	0,5	0,6

6.3.2 Total investment needs for the 1990's and 2000

Taking the data available from Tables 4.6-1 to 4.6-4 the total investment needs can be calculated for the mini-fertilizer production units in the developing countries. It is supposed that about two-thirds of the plants will be built at seaside, the others at remote locations. The total investment needs in million US Dollar (1983) are:

Table 6.3-2

Total investment needs

	up to 1990	1991-2000	total
Nitrogen plants	8600	14200	22800
Phosphate plants	800	1300	2100
Total	9400	15500	24900

It means that almost about 25 thousand millions US Dollar would be necessary up to 2000 for establishing nitrogen and phosphate fertilizer plants on mini-scale in the developing countries.

To this sum the cost of the developing of the adequate handling and distribution system must be added, which can be estimated about 10 billion US Dollar.

This system must be developed in case of supplying the farms with imported fertilizers, too. Thus the developing of distribution and warehouse system is not connected so much with the fertilizer industry as with the agriculture.

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QUESTIONNAIRE

Mini-Fertilizer Plant Projects

(please check appropriate box)

	yes	no
(1) Were the data contained in the study useful?	☐	☐
(2) Was the analysis sound?	☐	☐
(3) Was the information provided new?	☐	☐
(4) Did you agree with the conclusion?	☐	☐
(5) Did you find the recommendations sound?	☐	☐
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